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MARCH 1961

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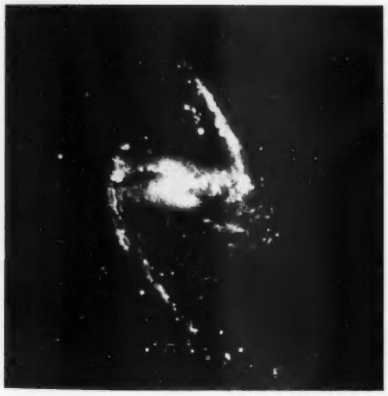

The galaxy NGC1365, a young barred spiral of type SBc.
H.M. Astronomer at the Cape

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FASHION IN RESEARCH

HONOR B. FELL

As I was casting my mind back over my long protoplasmic past, searching rather desperately for a suitable topic for this address, it suddenly struck me what an important part fashion had played in the development of our science during the past forty years. It occurred to me that this would make a rather suitable subject for a female president at a Paris congress, so this is what I am going to talk about: fashion in cell biology.

Sartorially speaking we are probably not an outstandingly fashionable group, but where our research is concerned, we can be as fashion-conscious as the most elegant woman in Paris.

The effect on scientific progress of this deference to fashion is quite interesting, and I propose to consider the various ways in which it operates, and whether on the whole its effect on our science is good or bad.

FASHION DESIGNERS

Sometimes scientific fashions are set quite suddenly by individual research workers. These fashion designers are, of course, a very small minority of the scientific population and are of different types. A few set fashions because they are endowed with a creative intelligence that is far above the common run (the late Ross Harrison was one of these); by the time their achievement has become fashionable, they themselves have usually lost interest in it and gone on to something else. Some have unusual technological talents and devise a technique that opens a new gateway to knowledge. But a fair proportion are quite ordinary people. For example, one of us may have one of those gorgeous strokes of luck that occasionally reward the observant and accidentally stumble on something new and exciting that attracts general attention. Or he may be gifted with unusual plausibility and be well versed in the art of scientific salesmanship. Or again, he may belong to that small group who are not fashion-conscious but pursue their own way, heedless of the prevailing mode; then one day such a person may find that for one reason or another his work has suddenly caught on, and behold! to his delighted surprise (for he is only human) he too becomes a leader of fashion.

Those who initiate fashions in research do not always receive their just reward. Sometimes a good idea or a new fact is not accepted when first published; the author may be subjected to severe criticism and have to fight for his brain-child. Then subsequent investigations show that he was right after all. His idea or his discovery becomes widely accepted, a large literature grows up around it and, finally, nobody remembers who originally thought of it. Those who set fashions in technique often fare better because their names usually get attached to their methods, since this is a labour-saving device for later authors.

THE FASHION FOLLOWERS

The motives that prompt the rest of us to follow fashions in research are various and not always estimable. Let us consider first some of the reasons why a new technique "catches on". The obvious and legitimate reason—that it is likely to provide an answer to many people's current problems—naturally accounts for much of its sudden popularity, but not for all. Some techniques become fashionable partly because they are difficult, expensive, or (better still) both, and this gives them a certain snob value; they are, as it were, the mink coats of research. Other techniques become fashionable for exactly the opposite reason—because they are so cheap and simple that anyone can use them, and yet they are *new*, and that in itself confers upon them a certain prestige.

When an important new discovery is made, it usually presents the broad outlines of a new picture, but the details have yet to be filled in. Very few of us are capable of drawing the broad outline, but if we are competent scientists we are perfectly capable of filling in the details, and this we rush to do, for a number of different reasons. Some do it out of passionate curiosity, because they long to see what the finished picture will be like; others do it because they are short or ideas, and the new work has disclosed some line of investigation that they are well qualified to follow. These are both very sound reasons. But less worthy motives sometimes operate. The field is new, and so prestige is to be gained from working in it; but what is even more important, being new, it is likely to attract money from granting bodies.

And this, I think, brings us to a rather pernicious aspect of fashion in research. In general, the waves of interest in something fresh that constantly sweep through our world are vital to its well-being, and without them research would indeed be stagnant and dreary. But rushing after new things merely because they are new (or what is more commonly termed "jumping on the band wagon") is another matter; it leads to the abandonment of existing lines of work that ought to be carried much farther, and even to contempt for the realities of nature, as in the disdain for structure that was such a regrettable fashion in cell biology a few years ago.

So where do we stand in this matter—is fashion in cell biology to be deplored or encouraged? Whichever way you decide to answer this question, the fact remains that hundreds of us have converged on Paris from all over the world for the sole purpose of watching what I am sure will be a magnificent display of all the latest modes—of course I mean in cell biology!

Excerpts from the Presidential Address delivered at the 1960 Paris meeting of the International Society for Cell Biology; reprinted from *Science* by permission. Dr Fell, F.R.S., is the Director of the Strangeways Research Laboratory, Cambridge.

dehydrated food

Drying food to preserve it is a technique of considerable antiquity, inevitably so in a world of seasonal food supply. Not that early examples of preserved food were to everyone's taste. There are still some primitive people who prefer a dish of well-rotted fish when there is no fresh food to be had; but they are a minority.

The earliest records of food drying go back to the Sumerians in 3300 B.C. Sun drying was used then, and continued to be used solely, until towards the end of the 18th century when stove and tunnel drying were introduced. But survival was always the prime motive, and while the quality of the dried foods was distinctive—and sometimes interesting—it did not always approximate to that of the fresh food from which it was prepared.

Other means of preserving food have been developed of course—pickling, curing, canning, etc.—and have their own virtues, but they result again in quite distinctive food products.

With quick-freezing there was a major breakthrough—as it were—to preserved food with the quality of fresh food. Now dehydration is coming forward again with new concepts, which give it greater potential to compete with fresh food on its merits, and so to be complementary to quick-freezing. Much of the spadework of this new approach has been carried out by such people as Ede, Marshall and Flosdorf. Unilever are already active in this work, in which success will depend not only on technical advances in method—spraydrying, freezedrying, airdrying, etc.—but equally on a knowledge of breed or strain characteristics, of growth behaviour, of pre-treatment of the fresh food and post-treatment of the dehydrated food.

In Unilever Research, then, Graham, Dow, Evans, Taylor and Withers are actively investigating all these related problems of food dehydration—basic and applied.

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THE PROGRESS OF SCIENCE

NEW LIGHT ON FUNDAMENTAL STRUCTURE OF MATTER

An experiment at CERN that took two years to prepare has produced some results that are important to a deeper knowledge of the fundamental structure of matter.

It has shown, first, that the mu-meson, or muon (an intermediate mass particle that is 207 times as heavy as an electron) can be visualised as a sphere with a radius no larger than 0·3 fermi, or $0{\cdot}3 \times 10^{-13}$ cm. and is more like a heavy electron than was thought previously.

It showed, second, that the laws of quantum electrodynamics are valid down to 0·7 fermi and, third, that any *fundamental length* which one may think of introducing as a limit to the relativistic invariance of physics is less than 0·2 fermi.

The experiment centred around the measurement of one of the physical characteristics of the muon—its magnetic moment. If the experimentally derived result happened to equal the calculated value that was based on the assumption that the muon was a heavy electron, then it would be apparent that the muon was, in fact, very much like a heavy electron. This finding, in addition, would establish the validity of quantum electrodynamics and other fundamental assumptions that were used in the calculation. It would also establish an upper limit for any *fundamental length*.

This is just what happened. The experimental value of the muon's magnetic moment checked the theoretically predicted figure to within two parts in 100,000.

CELLS DIVIDE FASTER IN SPACE

The effects of orbital space flight on some of the living organisms sent aloft in Soviet satellites were made public for the first time at a meeting of the biology department of the U.S.S.R. Academy of Sciences last month.

The biochemist Norair Sisakyan reported that the processes of cellular division in pea, maize, and wheat seeds were speeded up, and that definite modifications were noticed in the division of cells in bone-marrow samples from mice. The stimulating and, to some extent, harmful effect was not exerted by one factor alone but by a whole complex of factors, Academician Sisakyan noted, including weightlessness, radiation, and the high accelerations of launch and re-entry. Although the processes of cell division were affected, no major effects on the physiological functions of the organisms were apparent or would be expected as long as they were kept away from the great radiation belts, he added.

LONG-RANGE RADIO TRANSMISSION THROUGH "DUCTS"

U.S. Navy scientists have succeeded in transmitting radio signals over unusually long distances through "ducts" formed between wet and dry layers of air. They report that signals have been sent from California to Hawaii, a distance of 2600 miles; the ordinary range of these signals would be about 575 miles.

The phenomenon is undergoing intensive study; knowledge of the ducts is still too limited for practical use at the present time.

NEW EAST GERMAN TELESCOPE

A 2-metre (79-in.) universal reflecting telescope with four different optical arrangements to cover the entire field of astronomical and astrophysical investigations has just been installed in the newly-erected Karl-Schwarzchild Observatory in Tautenberg, near Jena. Designed and built by VEB Carl Zeiss JENA, it has been placed at the disposal of the East German Academy of Sciences.

The largest telescope of its kind, the four optical arrangements include:

A Schmidt system for examining the structure of the Milky Way, permitting 24×24 cm. photographs of 11 sq. degrees of sky.

A quasi-Newton system (with high light-gathering power) for the individual examination of cosmic gas clouds, distant spiral nebulae, and other objects.

A quasi-Cassegrain system for investigations of faint stars by means of photoelectric photometry and spectrography.

A quasi-Coude system for studies of the fine spectral lines of stars.

The telescope has a square-sectioned tube body about 10 metres long, the moving parts weighing 65,000 kg (32·5 tons). Three more are being constructed—two for the Soviet Union and one for Czechoslovakia.

STEADY-STATE THEORY OF UNIVERSE QUESTIONED

Measurements of the intensities of radio sources over the past several years has led Prof. Martin Ryle and his associates to the conclusion that the "steady state" or "continuous creation" model of the universe "cannot represent the actual universe".

Ryle bases his conclusion on the fact that the intensity-distribution curve he obtained with the radio telescope at the Mullard Radio Astronomy Laboratory (Cambridge) does not fit the one calculated from the steady-state theory originated by Profs. Hoyle of Cambridge, Bondi of King's College (London), and Gold of Cornell (U.S.A.) when all three were at Cambridge.

"Looking" out to distances of 3000 million light years and beyond, Ryle said he found a larger number of radio

New 2-metre reflecting telescope with four different optical arrangements, built by Zeiss in East Germany. Size can be judged by size of men at lower right.

sources than predicted by the steady-state theory. Since looking out to this distance also means looking back in time at things as they were 3000 million years ago and more, Ryle feels that the finding of a higher-than-predicted number of radio stars means that the stars were more closely packed together when the universe was younger than they are at present. This would support the "big bang" theory which holds that the universe as we know it began with a cosmic explosion of a concentrated mass of matter; if the steady-state theory were right, the distribution 3000 million years ago would be the same as it is now (as observed at closer distances).

Hoyle's immediate reaction is that the steady-state theory is still very much alive —that Ryle's data only appears to contradict the intensity-distribution curve obtained by inserting one set of assumptions into the steady-state equations. Another equally valid set of assumptions will bring the steady-state-distribution curve in agreement with Ryle's measurements, he states, and, in fact, this has already been done.

Ryle's retort is that he (Ryle) is not a mathematician and is basing his conclusion only on the original prediction of intensity-distribution based on the steady-state model. Hoyle's reply to this is that he (Hoyle) has never predicted the intensity-distribution relationship (although others had) because he was aware of the difficulty of making the proper assumptions. "The curve can be worked out in an infinity of ways and depends on information we do not yet have," Hoyle states. "It is too early to say the steady-state theory has been contradicted."

Bondi's immediate reaction is somewhat different. He is calling, first, for a closer examination of the limits of error claimed by Ryle. If the errors are greater than Ryle claims, says Bondi, the steady-state model will not have been disproven. If the errors are within the limits claimed by Ryle, the steady-state theory is dead, he adds, although he admits Hoyle may have a satisfactory explanation.

Gold, too, disagrees with Ryle's conclusions, stating that he does not think Ryle's measurements provide a sound basis for such a verdict.

The work of Ryle and his associates at Cambridge consisted of three parts:

1. The determination of the nature, power, and distance of radio sources. From this information it was possible to calculate the relative number of sources which should be observed at different intensities (according to the various cosmological theories).

2. The exploration of effects which might affect the apparent numbers of sources observed at different intensities. (If the sources occurred mostly in clusters, for example, they might be observed individually when near but as a composite and more intense source when at a greater distance.)

3. The observation of the actual numbers of radio sources observed at different intensities, so that the pattern may be compared with those predicted by different cosmological theories.

Observations with the Cambridge radio telescope are to continue.

In the meantime, a group at Jodrell Bank (Manchester University) is carrying out measurements of the size of radio sources that should throw some more light on the structure of the universe, although it is too early to say if these measurements will help resolve the present controversy over the steady-state and big-bang theories.

The Cambridge and Manchester groups have both asked the Department of Scientific and Industrial Research for funds for larger radio telescopes that will give more refined measurements and permit them to look deeper into space.

A NOVEL AUTOMATIC DAM

An inflatable tubular dam of neoprene-nylon has been installed on the Los Angeles River in Southern California to divert water to an underground reservoir; during heavy rains, it automatically collapses, thereby preventing flooding.

The tube—150 ft. long and 30 ft. in circumference—is secured to the concrete river channel underneath. When inflated, it diverts the water trapped behind it into spreading-grounds, where the water percolates through the soil to the reservoir underground from whence it is eventually pumped into the city's distribution system. The tube collapses automatically when the water load on it increases to a certain point, however, thus preventing flooding during wet periods and severe storms. In the collapsed state, it lies flat so that debris cannot get caught up in it and the weather-resistant material has proved sufficiently strong to withstand wear by water-borne sand and rocks.

A series of tests carried out last year proved successful, and the dam is now in regular operation. California authorities estimate it will divert about £27,000 worth of water a year.

NEW LOCUST ATTACKS EXPECTED IN ASIA AND AFRICA

Young swarms of locusts are likely to invade India and Pakistan from May onwards, according to the London Anti-Locust Research Centre. Areas in Arabia and the Middle East may be invaded earlier and other young swarms are expected to move into Kenya, Southern Ethiopia, Tanganyika, and Uganda.

While present indications are that countries along the southern edge of the Sahara may only be invaded lightly from North-western Africa during May and June, they may well be invaded simultaneously on a larger scale from Arabia. (A middle-sized swarm of locusts devours 3000 tons of vegetation daily.)

A three-man FAO expedition has already left for the Sahara to begin a one-year study of the desert locust swarms which regularly attack more than sixty African and Asian countries. The team will carry out an extensive ecological survey of the principal areas of desert-locust infestation in Mauritania, Senegal, Mali, the western sector of the Algerian department of Saoura, and adjoining regions. This is to be one phase of an overall survey of all the main breeding grounds in Africa and Asia over the next four years under the $3·75 million (£1·34 million) United Nations Special Fund Desert Locust Project.

DETERGENTS, SKIDDING, AND RADIO-ISOTOPES

In recent years, synthetic detergents have caused serious difficulties in water purification. The foam collecting in the purification plant has made it difficult for the oxygen to get to the sewage, thereby slowing down the process. The foaming agent is resistant to bacterial attack and has been present in such high dilution, further dilution has been impossible and the addition of anti-foaming substances too expensive.

A solution to the problem is now available—at least in principle—with the discovery that molecular structure of detergents can be modified to make them much more susceptible to bacterial attack and, thus, more rapidly destroyed.

This development was one of those mentioned by Sir Harry Melville, Secretary of the Department of Scientific and Industrial Research, in a recent address on the work in various stations of the Department. The address was one of the Dalton Lectures of the Manchester and District Section of the Royal Institute of Chemistry.

Sir Harry also described the progress being made on the problem of skidding, new industrial applications of radio-isotopes, the prevention of rancidity in fats, the development of new ion-exchange processes for the demineralisation of water and the separation of uranium and thorium from ores, and the

structural modification of surfaces to promote the dropwise condensation of steam in condensers.

Skidding is a well-known cause of motoring accidents. It can be reduced by increasing the adhesion between tyre and road, one recent approach to the problem being the development of tyres that give a higher coefficient of friction. The chemical nature of the rubber is now known to be significant and "high hysteresis" treads have been produced, using copolymers of isobutylene and a small amount of isoprene. One disadvantage of these, however, is the price paid in the loss of energy transmission from the wheel to the road and the consequent increase in fuel consumption.

The use of radioisotopes for thickness gauges, the measurement of tool wear, and the study of diffusion processes is now very familiar. Some new applications in quality control include the use of calcium silicate labelled with Ca-45 to find its dispersion as a rubber filler, the tagging of benzene sulphonyl hydrizide with S-35 to follow its distribution during the blowing process in the manufacture of foam rubber, and the use of Cr-51 to investigate the penetration of chrome tan into leather. The variation of density across a tree trunk has been followed at the Forest Products Research Laboratory by measuring the beta radiation from C-14, the results to be used in the selection of the most suitable trees for building up forests.

LONDON'S NEW COMMUNICATION TOWER

The Post Office will begin construction on a 507-ft. tower in London this year to meet the communication needs of the coming decades.

The 54-ft.-diameter cylinder—expected to be ready for use in mid-1964—will be a dramatic symbol of a new era in communication as it rises high above the surrounding buildings to avoid any possible obstruction, present or future, to the information-laden waves pouring in and out. It will be used to relay television programmes between studios, control stations, and transmitters (but not for television broadcasts directly to the public), and will be a centre for radio broadcast links to the outside. It will also make it possible for the rapidly growing telephone system to expand easily. By 1980, twenty-four telephony systems, each capable of carrying 960 separate telephone conversations, are expected to be in operation from this centre, and the number could easily be doubled in the following twenty years. All of this will still leave room for over 100 television outlets, including colour. Expected to cost £1,500,000, the tower will be located next to the present Museum Telephone Exchange, which is already a focal point for television, radio, and telephone links.

A circular cross-section was adopted for a number of reasons, but the idea originated with the realisation that the top six floors that are to house the aerials should be made circular to simplify the problems of 360° transmission. The fifteen floors below (for apparatus and offices) were made circular to keep the form consistent and give the tower an elegant simplicity. The cylindrical shape offered the additional advantage of less wind resistance.

The aerial section—355 to 470 ft. above ground-level—will be clad with opaque plastic-type materials that produce the minimum interference with the incoming and outgoing signals; the permanent framing will be limited to a few isolated positions for the same reason. Large sections of the flooring in this part of the tower are to be demountable to allow for the installation of large pieces of equipment. A glassed-in viewing platform for the public will be provided on top.

The lower portion of the tower will be enclosed by two layers of glass with venetian blinds in between. This part of the tower will rest on a base that is half its diameter and 115 ft. high, this base necking down to a 20-ft. reinforced concrete shaft that goes up through the centre of the tower and out through the top. The lift and service cables will go up through the centre of this shaft and the lift motors and control gear will be housed in the 35-ft. section of the core that extends above the top floor of the tower.

The aerial section will not be a continuation of the lower section; instead, the aerial floor panels will be mounted on a hanging steel lantern framework suspended from the top of the reinforced concrete core.

Since steady wind forces on tall, enclosed towers can cause unstable transverse oscillations that build up to serious magnitudes, wind-tunnel tests of scale models have been carried out at the National Physical Laboratory to make certain the tower will be aerodynamically stable. The over-all stability will be increased by the bridge deck between the base of the tower and the main building at the 80-ft. level. Wind gusts of 70 m.p.h. are expected to produce deflections of six inches at the top, and the heat of the summer sun may produce movements of as much as two inches.

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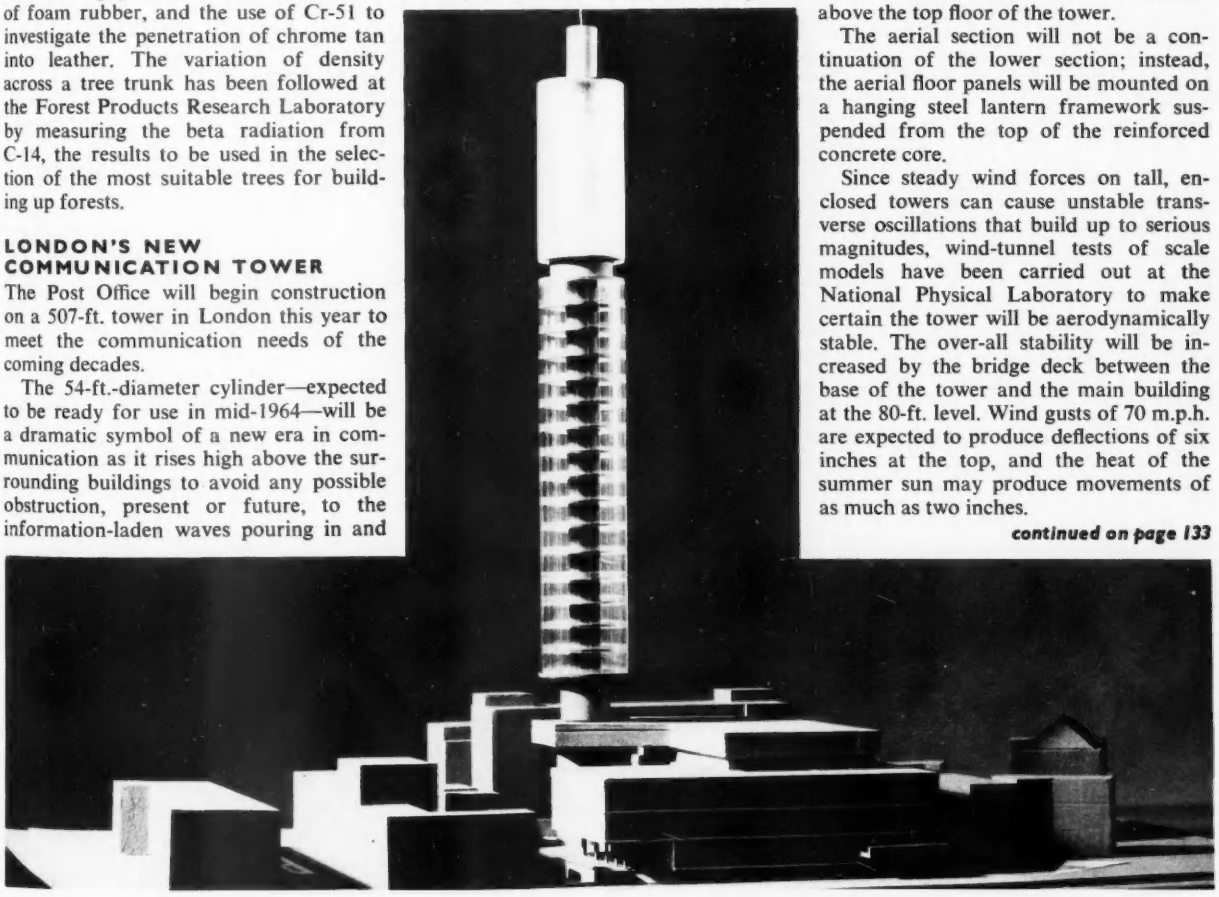


TONGUE AND BRAIN

GORDON H. WRIGHT

There seems to be a close link between the words we use and the anatomy of the human brain. This link might be examined with profit by the psychologists and philosophers.

The study of language has many aspects. In some of them, the body is ignored; this is the case with the philological, the literary, the philosophical, and the newer studies that are important to the communication engineer and the machine translator. In others, the body is taken into consideration; such is the case with studies of the phonetics and mechanics of speech, or the anatomical changes needed for the evolution of human speech from animal cries, or the speech disorders found in illnesses.

There has hitherto been no study of *vocabulary* that has taken account of the form and functions of the human body. Yet, if Man had no eyes, such words as *red* and *dark* and *glittering* would not exist and if Man had no limbs, he could not *wrestle*, *throw*, or *run*. Lacking the mobile organ in his mouth, he would not speak of *language*, *mother-tongue*, or *glossary*.

In general, it is easy to see how many of our words reflect the workings of our limbs and senses. This article will show how the words we use in ordinary speech can be correlated with certain details of the structure of the brain, and how one may be led to the conclusion that the words we use may *depend upon* the architecture of the brain.

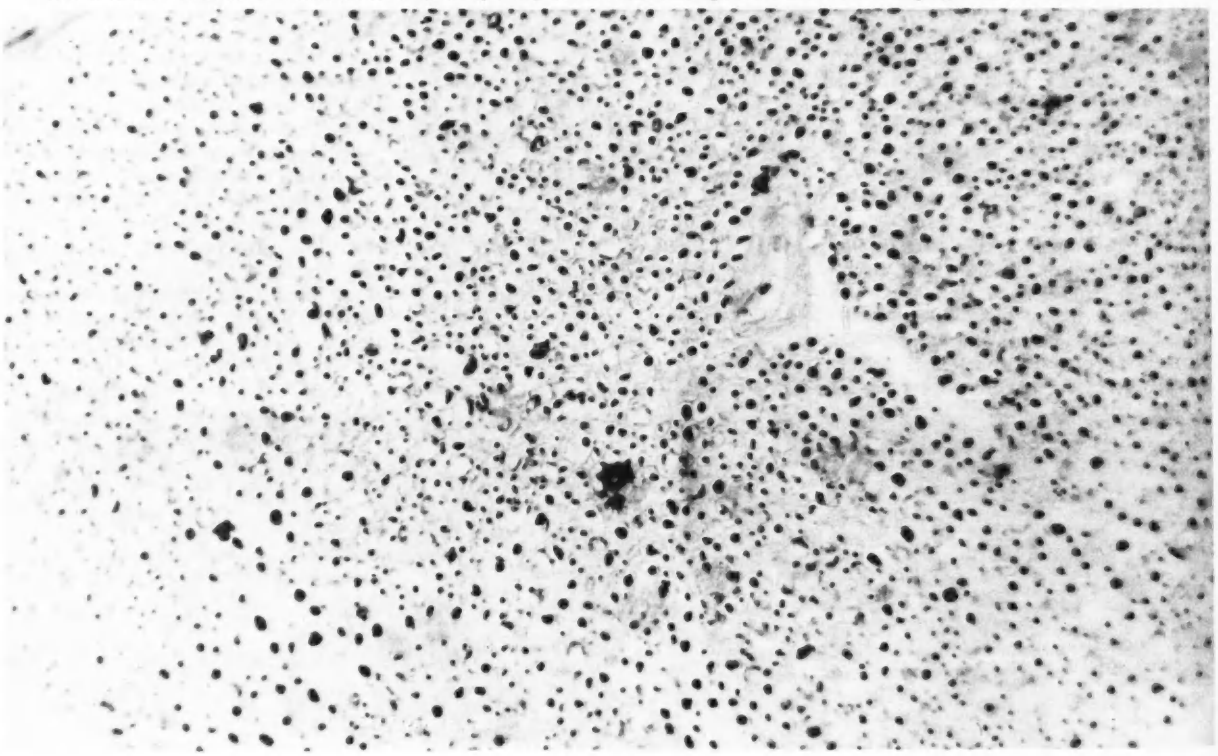
G. H. Wright, M.D., is Lecturer in Anatomy at Cambridge University.

THE LANGUAGE OF OUR PERCEPTION OF THE OUTSIDE WORLD

We shall first try to assess numerically how much of our vocabulary we owe to each of the senses. Some words, like *blue* and *loud* and *sweet*, are associated with only one of the senses but others, like *roundness* and *straightness*, are associated with two senses—vision and touch—and still others with three, four, or five. A *fish*, for example, can be seen, touched, smelled, tasted, and even heard.

In Miss Helen Eaton's "Semantic Frequency List",[3] words are arranged according to their meanings in the order of their average frequency of usage in written English, French, German, and Spanish. Among the 1020 words that were found to be used most frequently are 500 that refer to objects, events, ideas, and so on, that have a direct relationship to the human senses. There is an essential visual element in 478 of the 500 (95·6%) and an essential

FIG. 1. A cross-section of a human nerve bundle (500×). Most of the dark spots are nerve-fibres impregnated with silver.



element of touch or body-sense (joint-sense and muscle-sense) in 429 (85·8%). Compare these high figures with the 10·4% of words that have an auditory element and the 1% or fewer that necessarily refer to experiences of pain, temperature, taste, or smell.

The spatial senses—vision, touch, and body-sense—thus make a total contribution to our vocabulary that is nearly twenty times that from all the other senses combined.

THE SENSORY SYSTEMS IN MAN

It is clear, in a general way, that the number, variety, and complexity of the sense-data of any kind must depend upon the number of sensory nerve channels available from the sense organ to the cerebral cortex. A greater amount of "information" can be transmitted when there is a larger number of channels, just as more messages can be sent simultaneously over a large bundle of telephone lines than over a single line.

The number of nerve channels for each sense varies from person to person. Exact counts or even estimates are difficult to make but we now think it likely that the numbers reaching the brain on each side are about 1,000,000 from the eye, about 650,000 from touch and body-sense receptors, and about 30,000 from the ear. There are thought to be fewer nerve channels than this for smell, and far fewer for taste and temperature-sense. Part of a nerve-bundle cross-section that has been stained to show the separate nerve fibres can be seen in Fig. 1 at high magnification.

The number, variety, and complexity of the sense-data are also related to the size of the cerebral terminus of the sense organ—that is, upon the number of cerebral cells the sensory channels come into relation with. The very small cortical termini for temperature-sense and taste have only recently become known with any certainty and the exact positions for pain and smell are not yet settled. The fact that the cortical "areas" for the latter two have escaped discovery for so long would suggest that they also are small.

Vision, touch and body-sense, and hearing are the only senses that have a proven cerebral "representation" that is more than slight. Fig. 2 is a lateral view of the human cerebral hemisphere showing the cortical regions from which Penfield and Rasmussen were able to evoke sensation. The sites that we are particularly concerned with are the ones marked "primary", where the nerve channels from the sense organs end. Most of the visual "area" is on the medial aspect of the hemisphere, which is hidden. Owing to the folding of the cortex, parts of the other termini also are hidden from view. The best estimates available for these areas are 29 sq. cm. for vision, 16 sq. cm. for touch and body-sense which are mingled, and 3·5 sq. cm. for hearing.

Whatever the errors of these estimates, they show convincingly that (*a*) the visual system has the largest number of sensory channels and the largest number of cerebral cells, (*b*) the tactile system has the second largest numbers (perhaps about half as many as the visual), and (*c*) the auditory pathway has many fewer. Fig. 3 shows a comparison of these numbers with the relative contributions of the senses to vocabulary, all the numbers being expressed as percentages of the figures for vision.

There are, of course, great difficulties in the interpretation

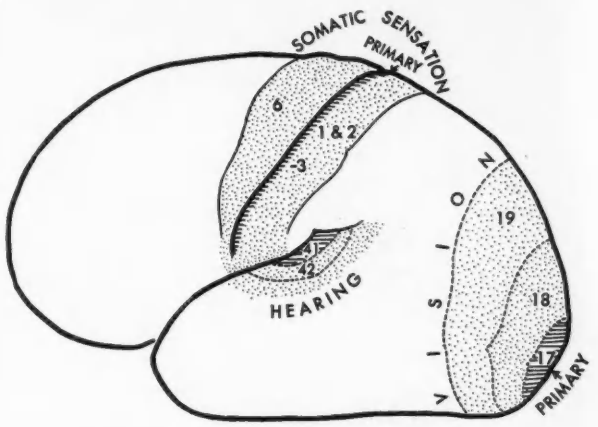


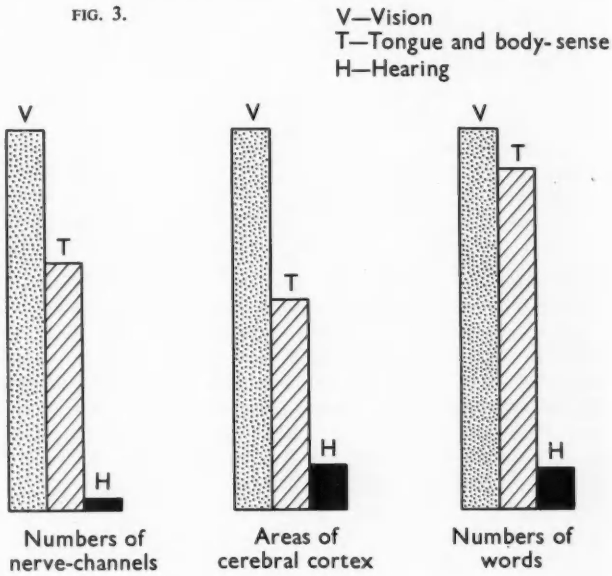
FIG. 2. A lateral view of the human cerebral hemisphere showing the cortical regions for visual, auditory, and somatic sensations.[5]

of these figures because of the "coding" of messages in the nerves but these anatomical findings do demonstrate, in a general way, that a sense organ with a large number of nerve channels leading to a large cerebral terminus is one which can send in a large amount of information and can therefore have much influence on thought—and vocabulary.

THE VOCABULARY OF MOVEMENT

In relating vocabulary to anatomy so far, we have considered only the five senses. Let us now try another approach, analysing the words used to name activities of other parts of the body. Many of our physical actions are performed primarily by one part of the body. We *smile* with muscles in the face, *hold* with muscles of the hand and arm, and *kick* with muscles of the leg and foot. In Miss Eaton's lists, there are among the first 1020 word groups

FIG. 3.



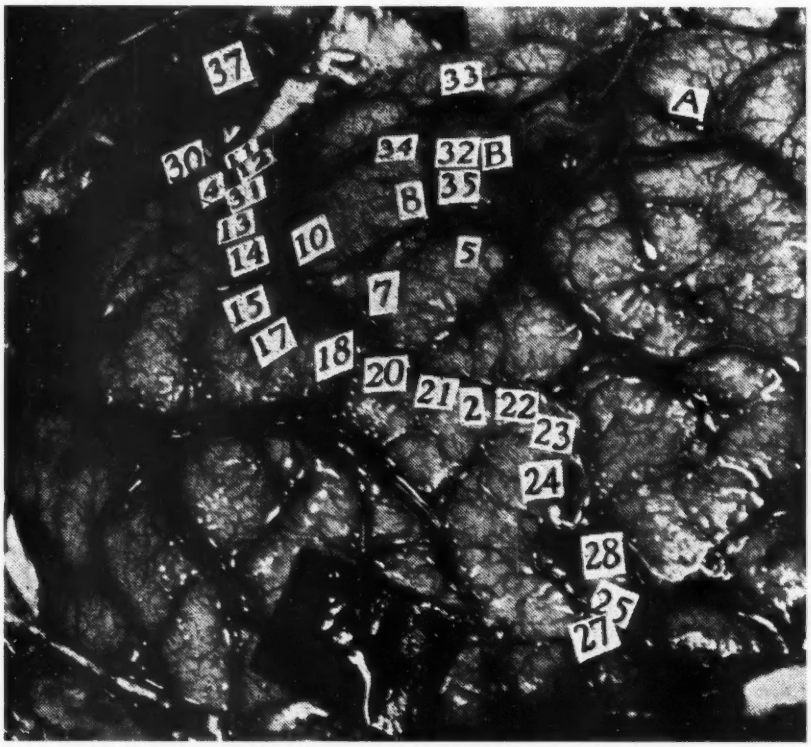


FIG. 4. Photograph of the exposed brain of a conscious patient. Numbers indicate points at which electrical stimulation (60 cycles/sec., sawtooth wave, 1 to 1·5 volts) began to produce a positive response.[5]

4. Left leg.
7. Left hand and forearm.
8. Left hand.
10. Left forearm.
11. Left foot.
13. Back, down to hips on the left.
14. Cheek and temple.
15. Forearm, thumb.
22. Index finger and thumb.
24. Thumb.
25. Tip of tongue.
27. Left side of tongue.
28. Left lower lip.
30. Left big toe.
32. Left leg.
33. Left leg.
34. Left forearm and hand.
37. Left leg.

121 verbs and 18 nouns that stand for actions that can be referred principally to one of the gross divisions of the body. Of these, the largest number apply to the head and neck (60), the next largest to the upper limb (49), the third largest to the lower limb (29), and only one to the trunk. The presence in the lists of only one entry for the trunk may be due in part to taboo, but it would be hard to find enough actions of the trunk to make even half the numbers there are for the leg, let alone the arm or head.

As these findings are too clear-cut to be due to chance, it is worth looking once again at the cerebral "representations". Movements confined to particular parts of the body can be produced by electrical stimulation of particular parts of the exposed cerebral cortex. This has been shown by many brain surgeons and notably by Penfield and his associates in Montreal, who have arrived at reliable estimates of the relative areas of cortex devoted to different parts of the body (see Fig. 4). Large areas are devoted to the parts of the body that are capable of highly skilled movements whilst relatively small areas are concerned with those parts that perform simple, rather hum-drum tasks. In their book on the cerebral cortex of Man,[5] Penfield and Rasmussen present these facts in a series of cartoons, one of which is shown in Fig. 5. The relative cortical areas devoted to movements of the four main regions of the body (worked out from the lengths of the block lines in the cartoon) are as follows: 41% for the head and neck, 35% for the upper limb, 22% for the lower limb, and 2% for the trunk.

Thus we see that it is the parts of the body having the largest "representation" in the cerebral cortex that make the biggest contribution to our vocabulary of movement.

Hence, the vocabulary of our relationships with the outside world, both as perceivers and as doers, is determined in part by the architecture of the brain. But what of our relationships with the "inside" world—the world of our thoughts and emotions? As a first step in this direction, let us examine certain metaphors.

THE LANGUAGE OF THOUGHT AND EMOTION

John Locke was the first in modern times to write of the great importance to philosophy of a study of language, and to draw attention to the ubiquity of veiled metaphors derived from our sensory experiences. Near the beginning of Book III of "An Essay Concerning Humane Understanding" (1690), Locke wrote:

"It may also lead us a little towards the original of all our notions and knowledge, if we remark how great a dependence our words have on common sensible ideas; and how those that are made use of to stand for actions and notions quite removed from sense, have their rise from thence, and from obvious sensible ideas are transferred to more abstruse significations, and made to stand for ideas that come not under the cognizance of our senses: e.g., to 'imagine, apprehend, adhere, conceive, instil . . .' etc., are all words taken from the operations of sensible things, and applied to certain modes of thinking. Spirit, in its primary signification, is 'breath'; angel, a 'messenger': and I doubt not but, if we could trace them to their sources, we should find, in all languages, the names which stand for things that fall not under our senses to have had their first rise from sensible ideas."

Many later philosophers and philologists, some casually and some more systematically, have drawn attention to the necessity of expressing abstract ideas in words that are derived from the language of sensation and perception, but none has examined in detail the relationship of these words to the various sense-organs and parts of the body.

Grafton Elliot Smith, anatomist, anthropologist, and Egyptologist, in his "Essays on the Evolution of Man"[6] drew attention to the significance of such metaphors as "foresight" and "insight" when considered in relation to the great development of the visual system of the primate brain, but this seems to be the only recorded attempt to give a neurological account of metaphor. Writings about metaphor, as indeed about language in general, have been overwhelmingly literary, linguistic, or philosophical.

Two large groups of metaphors are immediately amenable to neurological analysis, however—those that are expressed in the language of sensation and perception, and those that are based on movements of parts of the human body.

METAPHORS FROM SENSATION AND PERCEPTION

Metaphors based on colour, hearing, smell, taste, temperature-sensations and pain are mostly obvious metaphors —colourful and useful but easily dispensed with. They seem to have been invented for effect and are used deliberately as metaphors. We may be *yellow* (cowardly), have *rosy* prospects, or see *red*. We talk of *loud* clothes or a *nagging* conscience. If we disapprove of something, we may say it is in bad *taste* or, more bluntly, that it *stinks*. We would rather hear *hot* news than *hot* air, and we may *feel the pinch* or be *cut to the quick*.

These metaphors are nearly always uncomplicated, referring to one species of sensation or perception and one only. The same is often true of metaphors based on vision (apart from colour) but not of other visual metaphors or those involving sensations of touch or pressure, or muscle and joint sensations.

Vision. Metaphors that are based on vision, apart from colour, are numerous and significant—*short-sighted, illuminating, enlightened, transparent* and *lucid, evident, illustrious, illustrative,* and *invidious* are but a few of them. Their figurative nature generally escapes notice, even when they are not *obscured* by their Latin origins. For example, "see" is used frequently in contexts entirely divorced from perception, meaning understand, realise, be aware, and so on. "Look here" often means "pay attention" rather than "use your eyes".

Touch. The word *touch* is a most fruitful begetter of metaphors. We keep in *touch* with friends or in *contact* with reality, and have a sure *touch* or the common *touch,* and exercise *tact*. We may be *touched* to pity or just *touched* (that is, mad). We may receive *tangible* benefits or tell *palpable* untruths. Most useful in metaphor are many words standing for the "primary qualities" of matter that are perceived by the sense of touch—*bias, inertia* and *weight, heavy* and *light, stiff* and *flexible, strong* and *weak, hard* and *soft, rough* and *smooth, malleable, brittle,* and *impenetrable.*

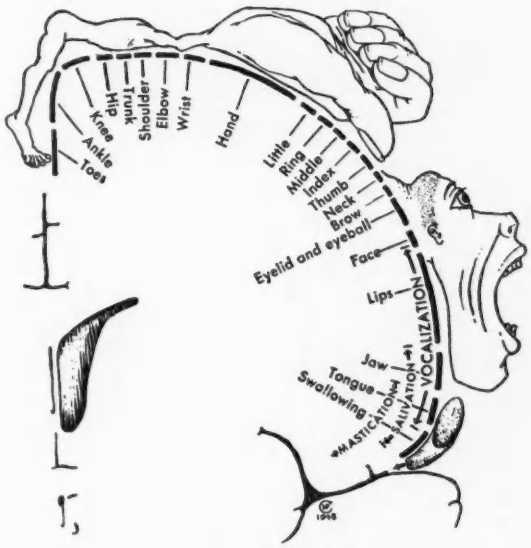


FIG. 5. A cartoon from Penfield and Rasmussen's book "The Cerebral Cortex of Man". The positions and sizes of the parts of the body shown indicate the positions and sizes of the areas of the cerebral cortex from which movements can be elicited. The heavy lines which outline the cerebral hemisphere give a more accurate measure of the cortical areas for the various parts of the body.

To express ideas of reality, certainty, or lastingness in abstract fields, we often use metaphors based on those properties of matter that are known to us by the sense of touch—such words as *solid, rock-like, weighty, enduring* (that is, hard), *substantial, imperishable.* Implicit in them is the idea that we can know the reality of things best by touching them.

Broad[1] has remarked that it is ". . . a natural, if paradoxical, way of speaking to say that seeing seems to 'bring us into direct *contact* with *remote* objects.' " An experimental neurologist discussing a problem of consciousness in an animal asked: "Shall we say 'awareness'? 'Consciousness' is a much harder word to *get your fingers on.*"

Of words for "touching" in the Indo-European languages, Buck[2] writes:

"In contrast to the words for the other senses, there is no important inherited group of cognates for "touch" or "feel". The words reflect a great variety of notions such as grasp, seize, catch, strike, stroke, tear, adhere, approach, and reach, involving contact or sudden motion . . ."

The importance of the hand as an organ of touch is implicit in many of these words for "touch"; indeed, the English words "feel" and "palm" are from the same root.

According to Buck, many of the Indo-European languages have no distinctive verb for "perceive by touch". The meaning is expressed by the generic words for "perceive by the senses"—words that are not restricted to the sense perceptions but may be used also in a wider sense for "perceiving" mentally or "feeling" emotionally.

Thus we see that the sense of touch differs in two important ways from the other senses—in its close association with movement of the hand, and in the great generality of the verbs for perceiving by touch.

Perceptual Space. A great many metaphors are based on our perceptions of shape, size, direction, and position—such as *square* deal and *round* condemnation, *broad*-mindedness and *shallowness, high* ideals and *deep* feelings, *uphill* task and *slough* of despond, *eccentricity* (off-centredness) and *normality* (originally squareness). They look a little ridiculous when paraded like this but they are honourable and useful *expressions* ("out-squeezings") whose figurative nature generally passes unnoticed. The terminology of perceptual space is also used to express the moral notions *right* and *wrong*. In Indo-European languages, the most common semantic source for *right* in the moral sense is "straight", according to Buck; for *wrong*, it is either "not-straight" or "crooked".

Metaphors based on perceptual space are ubiquitous and indispensable. They show that perceptual space is of the utmost importance in our abstract thoughts as well as in our thoughts about the outside, concrete world. This is further illustrated by the way in which, in some people's minds, the cardinal numbers are habitually ranged in a "number form" and similar spatial patterns are formed by the minutes of the hour, days of the week, months and seasons of the year, the seven ages of Man, the centuries, the alphabet, and the musical scale.

METAPHORS FROM MOVEMENT

A great many verbs of movement can be used figuratively, some of them in several different ways. Most of the verbs that stand for abstract processes actually originated as metaphors based on perceptual movement; some of these are *deduce, infer, object, tolerate, compel, urge, intend, support,* and *impress*. It seems that the verbs which are the most useful as metaphors are those with the widest application in their concrete usages. Many of the ones that apply to muscular acts have reference to the hand rather than any other part of the body; such are *take, make, accept, form, put, show,* and *throw*. We may *take* a liking to, *take* exception to, *take* note of, *take* pains with, *take* delight in, *take* thought for, *take* steps to, *take* time, *take* on, or *take* umbrage. We can *make* a point, *make* play with, *make* common cause with, *make* war on, *make* do with, *make* over, or *make* merry.

The importance of the hand is shown in other metaphors. We talk of *back-handed* compliments and *handsome* apologies, and say *grasping* when we mean greedy. An orator may skilfully *handle* (but not *man-handle*) his hecklers. To understand something is to have a *grasp* of it. We may *seize* an opportunity or *clutch* at a straw.

Some of the metaphors are more obscure. *Manner* was originally "mode of handling" and *maintain* was "hold with the hand".

To summarise: The numerous and varied metaphors expressed in the language of matter, space, and movement we owe, in the last analysis, to our visual and tactile perceptions. These and the ones that are based more directly on the "primary qualities" are often much better disguised than those based on the "secondary qualities", so that we generally forget that they are in fact metaphors. They are used freely in all serious discussions and we would be lost without them. Even though our most abstract statements appear to be divorced from any reference to sense-perceptions, they are commonly couched in the language of perceptual space, matter, and movement.

The permeation of our language by perceptual metaphor has important consequences for psychology and philosophy; one cannot over-emphasise the powerful influence of our visual sense-perceptions and, still more, our tactile ones, upon our thoughts and upon the terms we use to express them. Is there a neurological explanation for the supremacy in language of the sense of touch?

DEVELOPMENT OF THE CEREBRAL CORTEX

In most vertebrates, touch and body-sense and vision are the senses most intimately involved in the control of the posture and movements of the animal. Their importance relative to the importance of the other senses increases as one surveys an evolutionary scale leading to the Primates and to Man. It is the high development of these particular senses in Man that has made possible his unique range of skilled movements (particularly of the hand) and his unique knowledge of the outside world. Alongside the increasing importance of these sense-organs, and to a lesser extent the ear, has marched the evolution of the cerebral cortex, especially the *neopallium*—that "new" part of the cortex which is peculiar to mammals and which must occupy a central position in any discussion of brain and mind.

In the eyes of the comparative anatomist, the neopallium is an organ for the carrying out of varied movements that are guided and made skilful by the detailed control of the organs of touch and body-sense, in particular, and also of the eye.

ON REFLECTION

The thoughts that have been provoked by this analysis put one in mind of the opening sentences of Middleton Murry's "Essay on Metaphor"[4]:

"Discussions of metaphor—there are not many of them—often strike us at first as superficial. Not until we have ourselves made the attempt to get farther do we begin to realize that the investigation of metaphors is curiously like the investigation of any of the primary data of consciousness: it cannot be pursued very far without our being led to the borderline of sanity. Metaphor is as ultimate as speech itself, and speech as ultimate as thought. If we try to penetrate them beyond a certain point, we find ourselves questioning the very faculty and instrument with which we are trying to penetrate them".

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MAGNETIC FIELDS IN GALAXIES

R. D. DAVIES

The little that is known about these fields has been pieced together from observations of starlight, cosmic rays, and radio emission. Efforts being made to learn more may clear up some of the riddles of cosmic phenomena, including the question of why the spiral structure of galaxies is so stable.

The strength of the magnetic field in the disc of the Milky Way is commonly accepted to be in the order of 10^{-5} oersted—about one hundred-thousandth of the magnetic field at the Earth's surface. Yet it is considered sufficiently strong to hold cosmic ray particles within the envelope of the Galaxy, line up dust particles in the galactic plane, and explain the low frequency radio signals emitted from the disc and halo of the Galaxy. It also appears that magnetic fields of this order are necessary to preserve the spiral structure of galaxies.

No optical scheme for measuring the strength of the magnetic field of this Galaxy directly has yet been devised, however. The phenomena listed above lead only to an estimate of its magnitude indirectly and by means of uncertain theories.

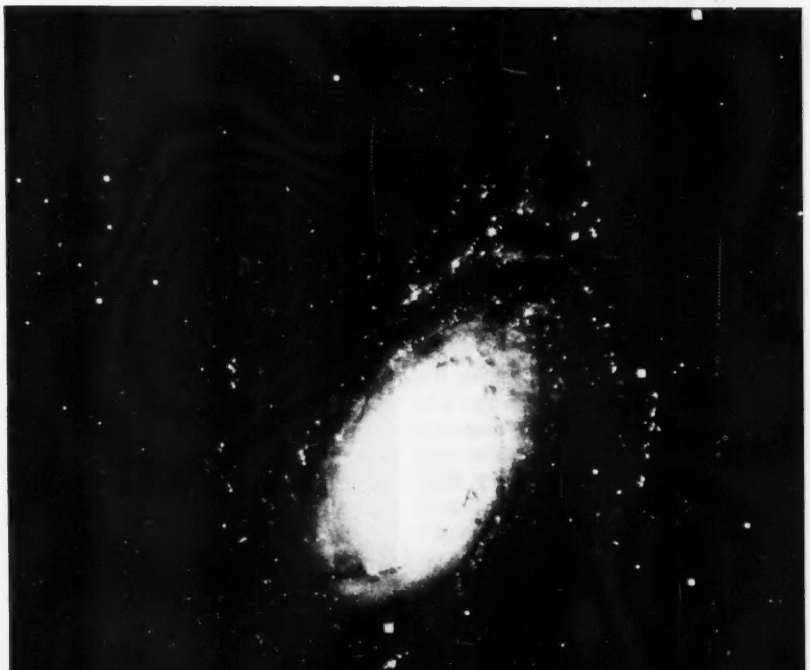
Radio measurements, on the other hand, have provided a direct means of showing that the magnetic field in the disc is less than 10^{-5} oersted and most likely less than half this value. This article will describe the various galactic phenomena in which a general magnetic field is involved and then discuss the consequences of the Jodrell Bank measurements using the Zeeman effect to determine the strength of galactic magnetic fields. But let us first examine briefly the basic features of the three major types of galaxies——the elliptical, the spiral, and the irregular. Since we are concerned here with magnetic fields and since such fields exert their influence principally on the gases scattered between the stars, the emphasis will be on the distribution and properties of the gaseous content of the galaxies.

Elliptical galaxies. These formations—the most common of the three—have a smooth elliptical outline and are considered to be in the most advanced state of galactic evolution. They contain very little interstellar hydrogen (the basic building material for stars) and, indeed, their stars have largely consumed their own supply of hydrogen and have become cool and red. Like the other types, the elliptical galaxies rotate and the stars are spread out in a circular disc. When seen at an angle, they appear elliptical.

Spiral galaxies. These come in a most fascinating variety of shapes, all of them having a dominating spiral pattern. The spiral arms which may sometimes be traced for a complete revolution are composed of dust, neutral hydrogen gas, and bright young stars that are rich in hydrogen, these arms lying in a more or less uniform medium of older stars. The spiral structure is apparently dependent upon the presence of the dust and gas; the thin dark lanes in the "older" spirals are due to the absorption of background starlight by dust.

FIG. 1. The nebula M81, a large galaxy with a spiral structure which is probably similar to that of our own Galaxy.

(Lick Observatory)



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The galaxy to which our solar system belongs—the Milky Way—is a spiral whose age is similar to M81 (Fig. 1), an intermediate spiral of type Sb. NGC1365 (cover) is a young barred spiral of type SBc. The spiral nature of our own galaxy was clearly established using the techniques of radio astronomy, for the optical astronomers were confined by the obscuring interstellar dust to only a small part of the galactic disc near the Sun. Radio signals are not affected by this dust. By good fortune, neutral hydrogen has a spectral line in the radio domain which allows us to plot its distribution throughout the plane of the Milky Way. A picture derived from observations at Sydney (in the Southern hemisphere) and Leiden (in the Northern hemisphere) is shown in Fig. 2. An elongated structure is clearly discernible but it is by no means certain that it represents a continuous structure spiralling outwards from the centre of the system. However, the least we may say is that the hydrogen composing some 2% of the mass of the galaxy is distributed in elongated clouds.

Irregular galaxies. The remaining group of galaxies—the irregulars—contain a large proportion of neutral hydrogen and young stars. Relatively rare, they are galaxies in an early stage of evolution in which the spiral structure—if it exists at all—is in an embryonic state. Our nearest neighbours outside our Galaxy—the Large and Small Magellanic Clouds (Fig. 3)—are irregulars with some 20% of their mass in the form of neutral hydrogen.

The spiral galaxies will receive the major part of our attention in the discussion of the part played by magnetic fields in galactic phenomena for two reasons: first, because the Milky Way (which can be examined in great detail) is a spiral and, second, because spirals contain appreciable amounts of gas on which magnetic fields can act (the general magnetic field of a galaxy having no effect on the movement of stars). We shall not consider the magnetic fields of individual stars which may reach values of 10^4 oersteds on their surfaces but which have no effect on the large-scale structure of a galaxy.

Let us now examine some of the various galactic phenomena in which a general magnetic field is involved—namely the polarisation of starlight, the

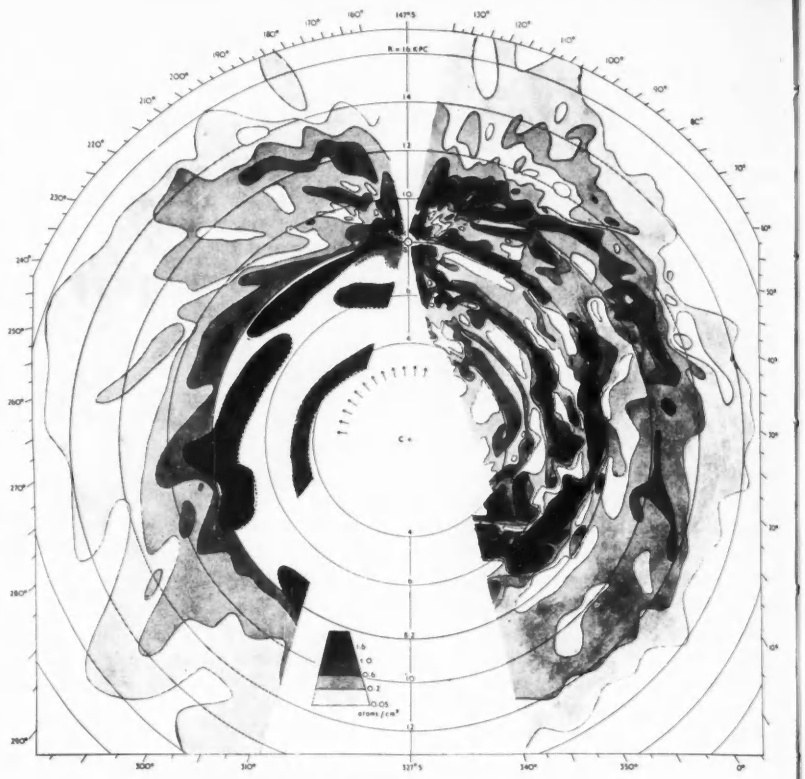


FIG. 2. A map of the distribution of neutral hydrogen in the Milky Way system, derived from measurements at a wavelength of 21 cm.
(*Oort, Kerr, and Westerhout.* Monthly Notices of the Royal Astronomical Society, *vol. 118*)

FIG. 3. The Large Magellanic Cloud. It is rotating and shows arms in an early stage of formation.
(*H.M. Astronomer at the Cape*)

distribution of cosmic rays, and the production of synchrotron radio emission —to see what light they can throw on the intensity of this field.

THE POLARISATION OF STARLIGHT

Hiltner of the Yerkes and McDonald Observatories found in 1949 that the light from distant stars is polarised and that the amount of polarisation is generally correlated with the amount of reddening. The accentuation of the red part of the spectrum is known to be an indicator of the quantity of interstellar dust between the star and the Earth (just as the redness of a sunset is a measure of the amount of fine dust or smoke in the atmosphere); the quantity of dust in the line of sight can also affect the amount of polarisation, as might be expected from the correlation.

Now, the mechanism by which a beam of randomly-polarised light can be given a net polarisation is a classical one: light reflected from a surface is slightly polarised in the direction perpendicular to the incident and reflected rays. If all the dust particles in an interstellar cloud are aligned in the same direction, as shown in Fig. 4, they will polarise the reflected starlight and leave the transmitted starlight with a net polarisation at right angles. The polarisation of the transmitted light coming from "neighbouring" stars will thus be in the same plane and will increase with an increase in the number of dust particles in the line of sight. The polarisation over large regions of interstellar space is illustrated in Fig. 5. Particles with a slightly flattened shape (having a long to short axis ratio of 1·5:1) can readily account for the observed effect; the major question is how the almost perfect alignment of dust particles can be produced.

The theory most widely accepted is that of Davis and Greenstein who suggested that the particles are paramagnetic (their magnetic properties being about a million times weaker than those of ferromagnetic materials like iron) and that they spin around their short axes, these axes lining up with the magnetic field. Indeed, this is how the axes must be aligned to account for the fact that the light from a distant star is partially polarised parallel to the spiral

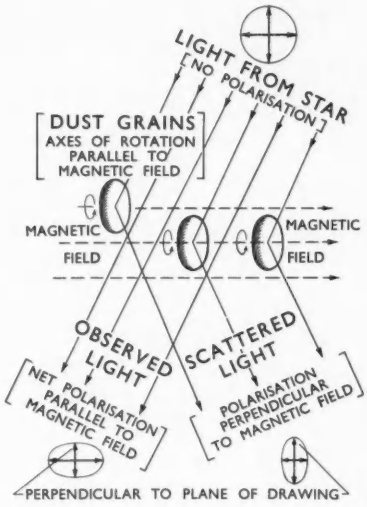


FIG. 4. Diagram showing how randomly polarised light from a star can be scattered differentially by dust grains, leaving the transmitted light with a net polarisation parallel to the magnetic field.

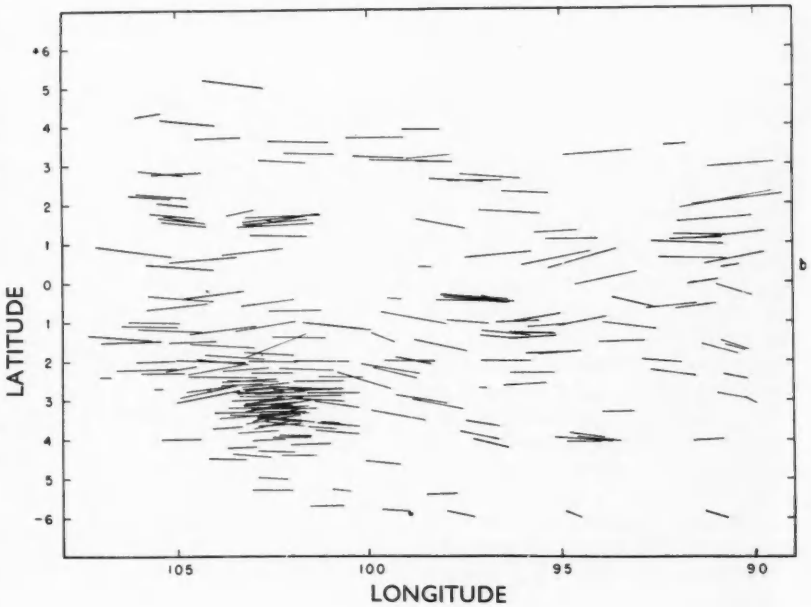
arms and, we may assume, parallel to the magnetic field (Fig. 4).

As already indicated, the theory does not give a clear measure of the magnitude of the magnetic field required to align the interstellar dust grains; a field somewhere between 10^{-4} and 10^{-5} oersted would certainly give the desired effect but an even smaller field might perhaps be adequate.

An alternative method of producing polarisation with interstellar dust is suggested by Platt of Chicago University who shows that all of the observed effects can be explained by using a quantum-mechanical description of the way in which very small particles about 10Å across interact with starlight. He still requires some process like that proposed by Davis and Greenstein to align his particles but gets us no closer to estimating the value of the magnetic field strength of the Galaxy.

Although the polarisation of starlight does not lead to an explicit value for the galactic field, it does give us a vital clue to its arrangement. Observations out to distances of 3000 parsecs (10,000 light years) show that the stars which lie in the plane of the Galaxy, in the direction opposite to the centre (where the line of sight cuts perpendicularly across the Orion and Perseus arms), have a polarisation that is remarkably parallel to the plane of the Milky Way (Fig. 5). This is the effect expected when our line of sight is perpendicular

FIG. 5. Polarisation of starlight coming from the vicinity of the anti-centre, along a line of sight almost perpendicular to the spiral arms of our Galaxy. The length and position of each line represents the strength and plane of polarisation of the light observed from a star. (*Dr W. A. Hilton*, Astrophysical Journal, *vol. 114*)



to the magnetic field. When we look along the spiral arms, the polarisation is random—an indication that we are looking along the magnetic field lines (Fig. 6). These observations lead to the conclusion that the magnetic field of the Galaxy closely follows the spiral arms; preliminary investigations by Hiltner of the giant Andromeda Nebula show that the polarisation found in groups of stars there follows a similar pattern of alignment.

COSMIC RAYS

Let us now examine the information cosmic ray studies have yielded about the galactic field.

Cosmic rays reach the Earth's surface in a variety of forms, some as electromagnetic radiation, some as elementary particles, and some as atomic nuclei. The intensity of this influx and its direction of arrival vary with time and with the location of the observer on the Earth's surface, this variability being a consequence of our living beneath the Earth's atmosphere and our proximity to the Sun (a variable emitter of cosmic rays). Primary cosmic rays which would be encountered in interstellar space have been shown to be isotropic (showing no preferred direction of travel) and consist only of atomic nuclei (principally the hydrogen nucleus, the proton).

The spatial energy density of these particles is, surprisingly enough, as large as the energy density of starlight—about one electron-volt ($1{\cdot}6\times10^{-12}$ ergs) per cu. cm. Most of the individual particles have energies in the 10^{8} to 10^{19} eV range.

The isotropy that is inferred is attributed to the presence of the magnetic field in the Galaxy, the deflecting action of such a field on the motion of an electrically charged particle being well known. Even if the cosmic rays did originate in the flat disc of the Galaxy which contains the bulk of the stars, their direction of flight would bear no resemblance to the direction in which they were ejected from a star or supernova explosion, for these particles would move in large spirals about the magnetic lines as shown in Fig. 7. The larger the energy, the greater the radius of the spiral, a proton moving across a field of 10^{-6} oersted with an energy of 10^{15} eV executing a spiral with a radius of 1 parsec.

When we consider the largest radius that is possible without the cosmic ray escaping from the Galaxy altogether, we see the possibility of deducing some information about the strength of the magnetic field from cosmic ray observations. Estimates show that so long as the radius of the spiral is less than one-tenth of the radius of the Galaxy, it has little chance of escaping; in this calculation, the Galaxy is assumed to include a magnetic halo that is roughly

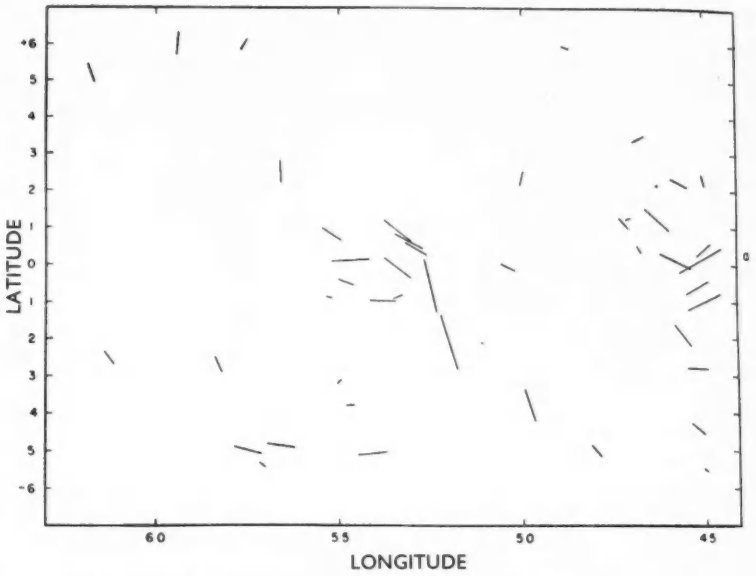
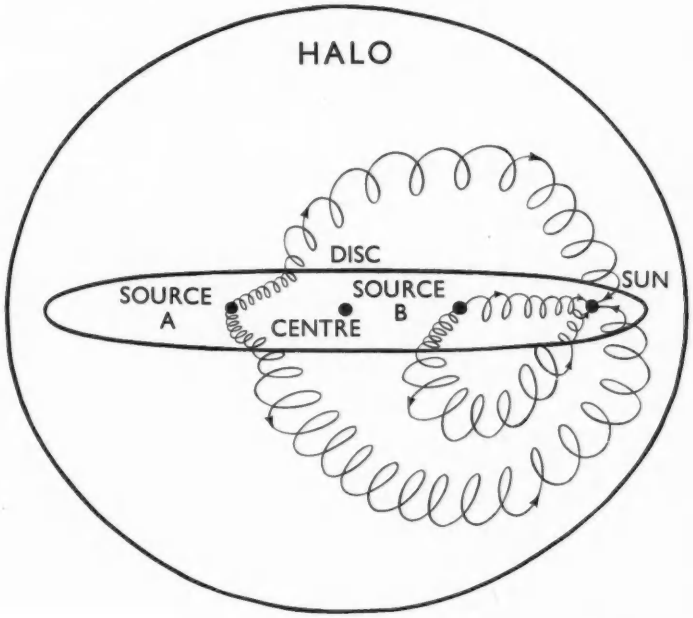


FIG. 6. Polarisation of light from stars in Cygnus, the line of sight being along a spiral arm. (*Dr W. A. Hilton*, Astrophysical Journal, *vol. 114*)

FIG. 7. Schematic diagram showing how the magnetic fields in the disc and halo of the galaxy make the cosmic rays ejected from arbitrary sources A and B arrive at our solar system from random directions.



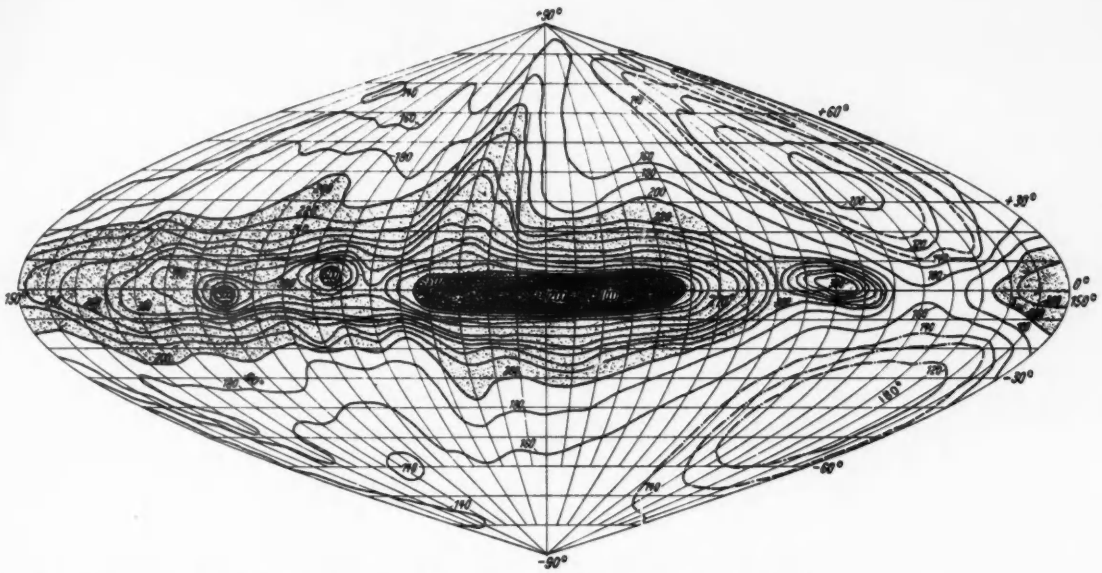


FIG. 8. A radio map of the sky at 200 Mc/s (1·5 metre wavelength). The concentration of the disc component towards the plane of the Galaxy is clearly evident; the halo has the broader distribution. Brightness temperatures are given in °K, the darkest parts being above 500°K with a temperature of 1200°K measured near the centre of the Galaxy.

(*J. H. Oort*, Handbuch der Physik, *LIII, Springer-Verlag*)

spherical with a radius of about 10,000 parsecs. (This halo will be discussed below). Since the most energetic of the cosmic ray particles will stay in the Galaxy only if it spirals with a radius of less than 1000 parsecs, the discovery of particles with energies of approximately 10^{19} eV indicates the magnetic field strength of the halo is in the order of 10^{-5} oersted (if it is assumed that these particles originate in this Galaxy and make at least one spiral before reaching the Earth). Since this magnitude of field strength is higher than that expected in the halo by a factor of 3, it would seem that the highest energy particle might not be held to the Galaxy.

It was with great interest that we learned about Rossi's detection of a cosmic ray particle with an energy of 2×10^{19} eV during the autumn of 1960 —the highest energy particle yet to be found. The particle was detected at the New Mexico station of the Massachusetts Institute of Technology and Rossi claims it must have come from the spaces between the galaxies because of its observed direction of flight. This discovery throws new light on the size of the magnetic field in the halo for it throws open the possibility that most of the high-energy particles—say greater than 10^{18} eV—are of extra-galactic origin and have been made isotropic (randomised) by the intergalactic field. The magnetic field of the halo would then need to be only about 10^{-6} oersted to impart isotropy to galactic cosmic rays.

Yet another approach can be made to this question of the magnetic field strength of the halo from a consideration of the energy density of cosmic rays and the magnetic field. So long as the energy density of the magnetic field is greater than that of the cosmic rays, the former will hold the latter; if this were not the case, the cosmic rays would push the magnetic fields aside and escape, and we would lose the observed isotropy. As noted above, the energy density of the cosmic rays is about 1 eV/cu. cm.; the corresponding magnetic field is 6×10^{-6} oersted. This, then, would be a lower limit for the field strength.

These arguments are radically altered, however, if there is enough material in the halo to make the associated gravitational energy density comparable with the other forms of energy.

A further theory requiring magnetic fields is Fermi's scheme for the production of cosmic ray particles in the interstellar medium—a scheme whereby charged particles of low energy are accelerated in regions of changing magnetic fields.

SYNCHROTRON RADIO EMISSION

Let us now see what information synchrotron radio emission can give us about the intensity of the galactic field.

A glance at a radio map of the sky at a wavelength 1·5 metres (Fig. 8) shows there are two components of galactic emission. One is confined to the disc of the Galaxy and is visible mainly in the central regions of the galactic plane; the other, the halo component, is more widely distributed, being almost spherical in shape with a radius of about 10,000 parsecs.

This picture of our Galaxy is confirmed by observing a similar one, M31, which also has a radio halo and disc. Extraterrestrial radio emission at these wavelengths is currently believed to originate in the synchrotron process—a process in which electrons of high energy (and therefore travelling near the speed of light) spiral around magnetic lines and simultaneously emit radio waves. This process has a tell-tale characteristic that often enables it to be distinguished from other likely processes—the emission (which may be light or radio waves) is polarised at right angles to the magnetic field. The Crab Nebula (the supernova of 1054 A.D.) was the first astronomical object in which this process was clearly identified.

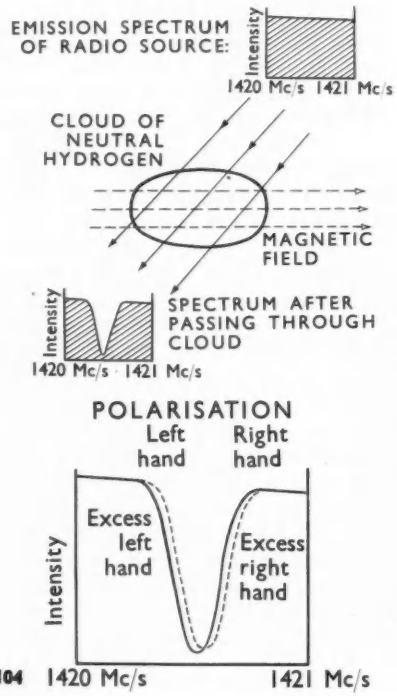
Optical and radio polarisation have also been detected in M87, the elliptical galaxy in Virgo with an unusual jet.

The high-speed electrons that take part in this process are believed to be secondaries arising from the collision of primary cosmic rays with hydrogen atoms in interstellar space. Like the cosmic rays, these secondaries will be distributed uniformly throughout the disc and halo of the Galaxy. Since the strength of the emission they produce varies roughly as the three-halves power of the magnetic field strength, measurements made to date indicate that the magnetic field strength of the halo is 6×10^{-6} oersted while that of the disc is 4×10^{-5} oersted—about seven times as high. Although the value for the halo is in agreement with that obtained from the cosmic ray approach, the value for the disc is rather high, particularly in view of the experiment described below.

THE "ZEEMAN" EXPERIMENT

The Zeeman effect is one of the classical phenomena of physics, showing the interaction of light and magnetic fields.

FIG. 9. (*a*) Diagram showing how a narrow absorption line in the spectrum of a radio source results when the radiation passes through a cloud of neutral hydrogen. (*b*) In the presence of a longitudinal magnetic field, the line is split into left- and right-hand circularly polarised components.



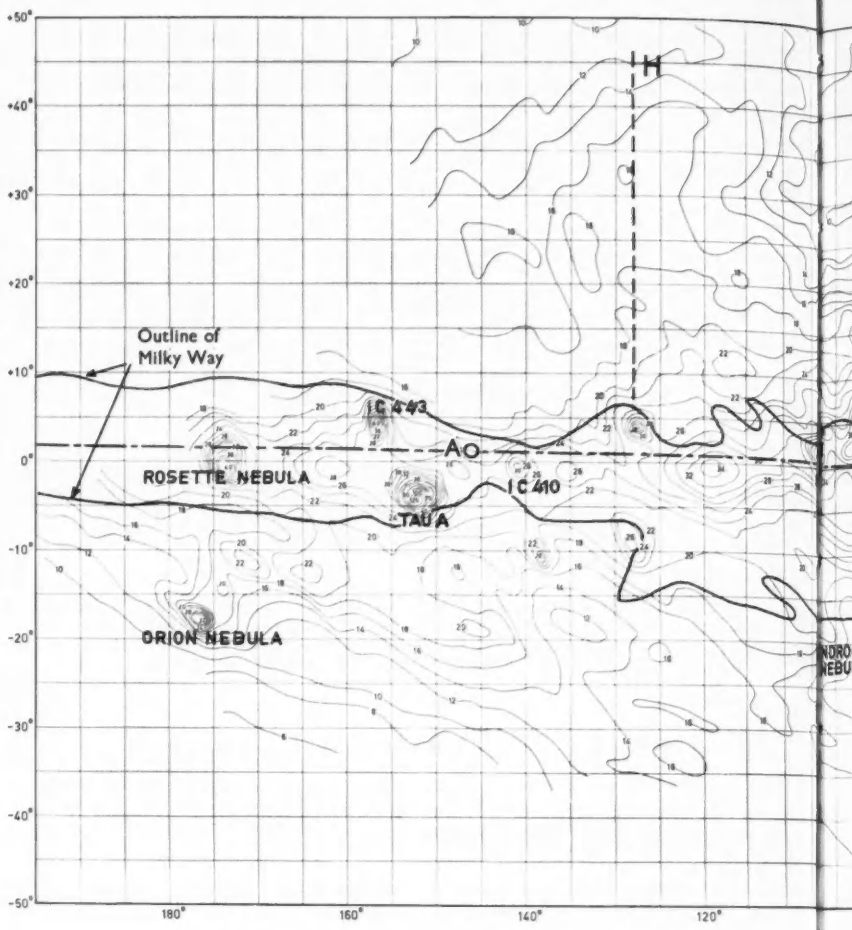
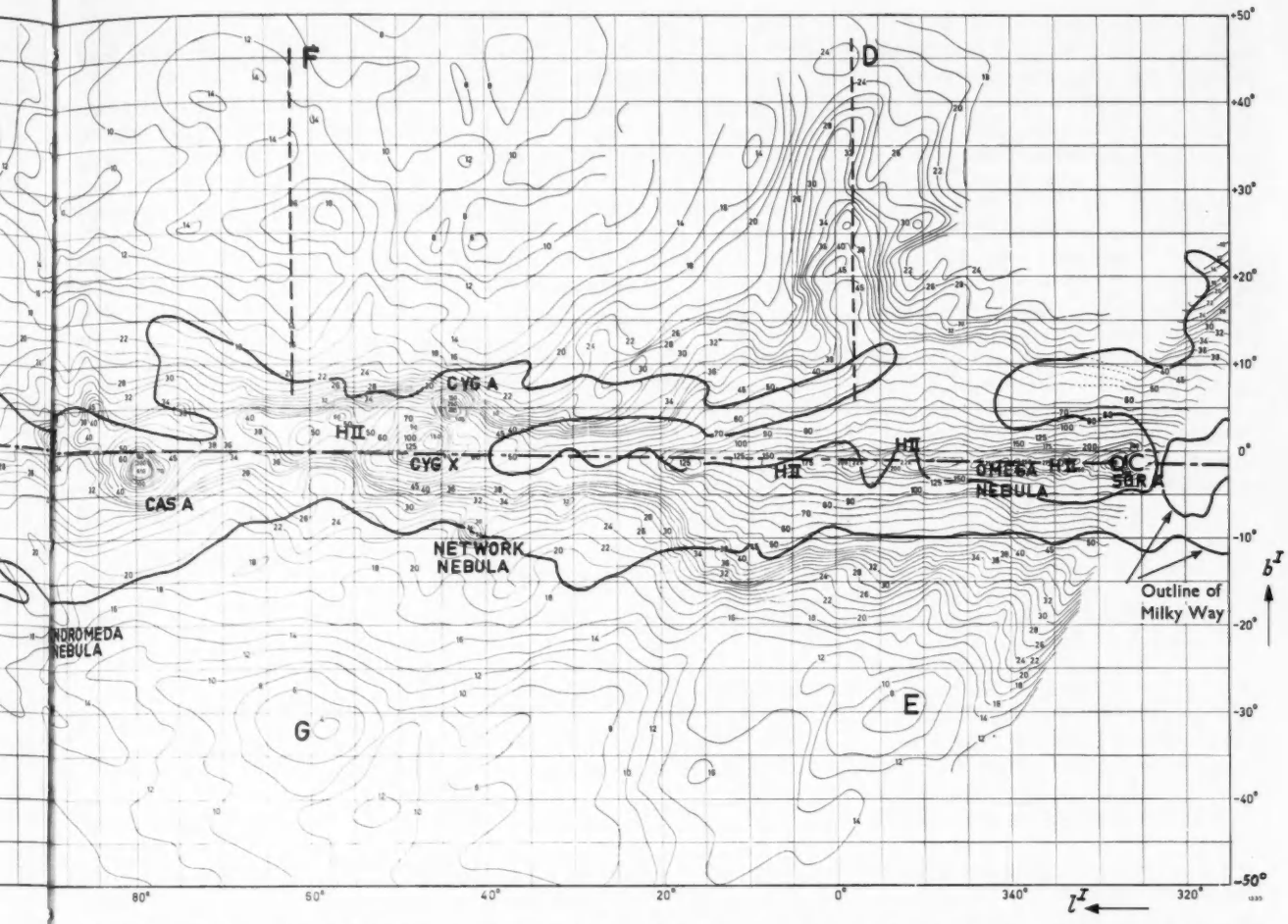


FIG. 10. A radio map of part of the sky at 400 Mc/s, made with the radio telescope at Dwingeloo, The Netherlands, showing large irregularities in emission. Brightness temperatures can be obtained by multiplying the numbers on the contour lines by 1·3°K. The region of the sky reproduced here comprises part of the Northern Milky Way. The outline of the Milky Way itself is also shown, the almost horizontal dot-dash line denoting its plane of symmetry. Looking out from our solar system, the centre of the galaxy is in the direction of the circle C; the anti-centre is in the direction of A. Some of the radio sources are identified; Cas A is in the direction of Cassiopeia, and Cyg A and Cyg X are in the direction of Cygnus. HII markings indicate some regions of hot ionised hydrogen.
(*Seeger, Stumpers, and van Hurck*, Philips Technical Review, *vol. 21, No. 11*)

In the normal Zeeman effect, a radio or visual spectral line that is generated in the presence of a magnetic field is split in frequency and the various components are polarised. The emission in the direction of the magnetic field is split into two components that are shifted by equal amounts to either side of the original frequency and circularly polarised in opposite directions. The frequency separation is small (only 2·8 Mc/s per oersted) and is independent of the frequency of the original emission line. For the hydrogen-alpha line at 6563 Å, a magnetic field of 2500 oersteds is required to separate the two components by 0·1 Å, an amount comparable to the line-width commonly observed in astronomy. The Babcocks at the Mount Wilson and Palomar Observatories, however, have successfully developed a technique for mapping the magnetic fields on the sun with an accuracy of better than 1 oersted (several thousand oersteds are encountered in medium-sized sunspots).

Bolton and Wild suggested in 1957 that this same technique might be used to measure the splitting of the 21 cm. radio line from hydrogen in the magnetic field



of the Galaxy. The great advantage of working in the radio domain was that frequency shifts of several tens of cycles/sec. (corresponding to magnetic fields in the order of 10^{-5} oersted) could be measured with considerable accuracy. The major requirement for accurate measurements was narrow, intense lines, and these are available in the absorption lines of the strong radio sources in the Galaxy.

Fig. 9(*a*) shows how the continuous emission from a radio source is partially absorbed by a cloud of neutral hydrogen in one of the spiral arms lying between the source and the observer. The width of this line is a function of the turbulent or thermal motions of the hydrogen atoms that make up the cloud. If the absorbing cloud is permeated by the magnetic field of the Galaxy, the absorption line will be split into two circularly-polarised components of opposite rotation, the amount of splitting depending on the component of the magnetic field in the line of sight as shown in Fig. 9(*b*).

In an experiment carried out at Jodrell Bank by Slater, Shuter, Wild, and the author, the receiver was switched between left- and right-hand circular polarisation as the absorption spectra of various sources were scanned in frequency, using a narrow bandwidth. If one side of the spectrum contained more of one polarisation than the other, a difference signal would have been visible on the output of the receiver.

Although many records were taken, no effect was found that could be attributed to a magnetic field; the results, though negative, established an upper limit for the magnetic field. Towards the Cassiopeia-A source (in a direction where, according to the measurements of star polarisation, the line of sight makes an angle of perhaps 30° or 40° with the magnetic field lines) the upper limit placed on the line-of-sight component of magnetic field strength is 5×10^{-6} oersted. This result was obtained for three clouds that may fairly be said to be representative of the interstellar medium. The measurement was a direct one and gives an unambiguous value for the field in the regions studied. It could only give too low an answer if the magnetic fields in the cloud were very irregular but this possibility is ruled out by the uniformity of the field found in the optical polarisation measurements.

CONSEQUENCES OF THE "ZEEMAN" EXPERIMENT

If we assume as a result of this Zeeman experiment that the magnetic field everywhere in the disc of our Galaxy is less than 6×10^{-6} oersted, we can re-examine the foregoing theories to see which, if any, need revision; we will also assume that the magnetic field in the halo is less than that in the disc.

In the discussion of the optical polarisation effects, we have seen that the

magnetic fields required to line up the particles cannot be precisely determined by theory; there is, consequently, no conflict with the observations. An adequate theory is needed to show that the lining up can be accomplished by magnetic fields less than 6×10^{-6} oersted.

The necessity for a stronger magnetic field to hold cosmic rays in the Galaxy and produce the observed isotropy has been removed by the discovery of a high energy cosmic ray extragalactic origin by Rossi. This now leaves open the possibility of an extragalactic origin of all high-energy cosmic rays with energies of more than, say 10^{15} eV. Cosmic rays with low energy, say less than 10^{10} eV., can easily be held and made isotropic by fields considerably weaker than 6×10^{-6} oersted. These cosmic rays must originate in this Galaxy since they contain the bulk of the integrated cosmic ray energy and it is difficult to imagine an extragalactic source of cosmic ray energy with a magnitude of $1{\cdot}6\times10^{-12}$ ergs/cu. cm. It is known that at least one star—the Sun—is a spasmodic source of low-energy cosmic rays; Biermann and others have suggested that the supernovae, flare stars, and ordinary stars are the source of all cosmic rays.

The conclusions from the Zeeman experiment contrast most strongly with the magnetic field requirements for synchrotron radio emission from the disc of the Galaxy. If the field in the disc is uniform, then its strength must be in the order of 4×10^{-5} oersted to give the emission measured; the Zeeman-derived value is only one-seventh of this. One way out of this dilemma is to postulate a uniform field of 6×10^{-6} oersted in the disc and, in addition, high-intensity randomly-oriented local fields of, say, 10^{-4} oersted. This would not only account for the observations noted above but would also explain why a group at the Mullard Radio Astronomy Observatory in Cambridge have failed to find any polarisation due to synchrotron emission in the uniform magnetic field of the disc (or halo).

But we now have to find possible sources for the high-intensity randomly-oriented local fields. These could be from nebulosities, perhaps supernova remnants which are regions of high local magnetic intensity. If the high magnetic fields in these regions last for up to 10^6 years, they will be sufficient to give the observed emission without invoking a uniform field of more than 6×10^{-6} oersted.

There may also be regions of higher-than-average magnetic intensity in the halo; large irregularities found in the radio emission from the halo by Seeger and his associates at Leiden Observatory point to such a possibility (Fig. 10).

THE SPIRAL STRUCTURE OF GALAXIES

One major question in astronomy is the stability of the spiral structure of galaxies. Here too magnetic fields may play an important role.

Spiral galaxies constitute about one-third of all the galaxies known and, on a statistical basis alone, spend some thousands of millions of years in the spiral form. Spiral galaxies do not rotate as rigid discs; the rotation rate in the outer regions decreases with the distance from the centre and, as a result, the gas and stars in each spiral arm fall behind the gas and stars in the next innermost arm. For example, the Perseus arm of our Galaxy is slipping backwards past the Orion arm (in which the Sun is located) at the rate of one revolution per 7×10^8 years. Thus, a new spiral arm would be formed during this period as depicted in Fig. 11 if the whole spiral structure was not obliterated in the process.

During the lifetime of this Galaxy, many arms should have been formed. Many galaxies have only one pair—the young galaxy NGC1365, for example—and even the most complex and older galaxies such as M81 show only two to three pairs. Why is it the galaxies do not show larger numbers of spiral arms?

One explanation suggested by a number of individuals is that the magnetic field of a galaxy revolves at a constant rate, providing a stable rotating reference frame. This would produce a simple spiral configuration throughout time. In order to exhibit the correct differential rotation speeds, the gas in the galaxy would have to move along the spiral arm. Since the stars would remain unaffected by the magnetic field, they would show a movement relative to this gas. Such a motion is indicated from 21-cm. and visual studies.

Although this may not be the final picture it is felt that a fuller understanding of the magnetic fields will provide an answer to the riddle of the spiral structure of the galaxies.

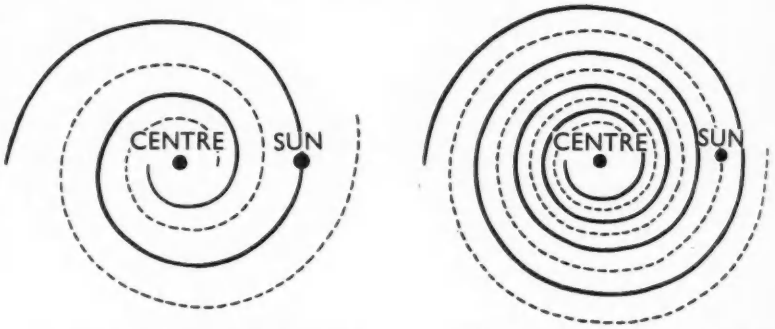


FIG. 11. (*a*) A schematic diagram of the spiral structure of our Galaxy at the present epoch.

(*b*) The appearance of the Galaxy in 700 million years under the influence of differential rotation alone.

One general consideration is important in this context. If a magnetic field is to control the motion of the gas in the spiral structure, the magnetic energy density should be greater than the kinetic energy of the gas. This would require an average magnetic field strength of more than 4×10^{-6} oersted.

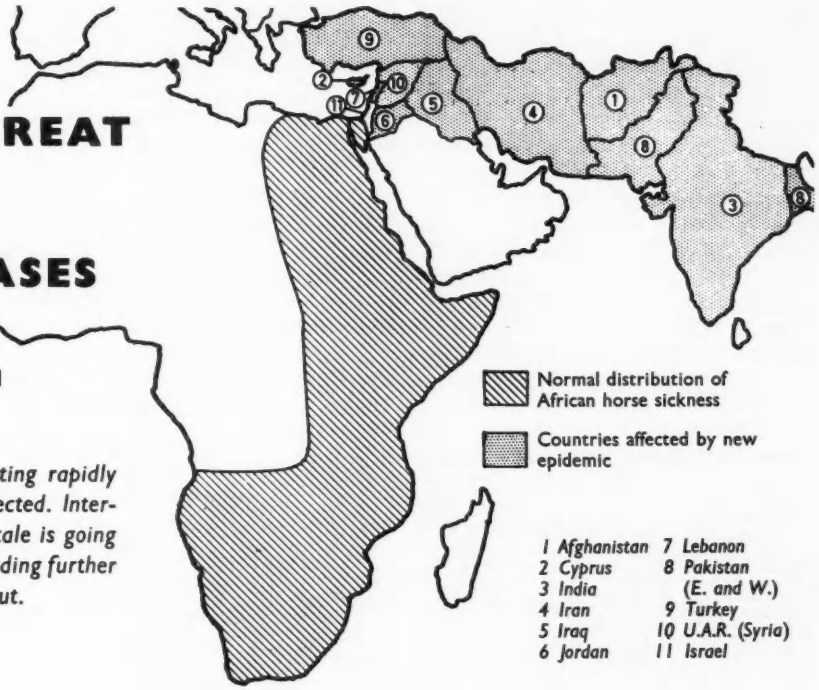
SUMMARY

All the galactic phenomena outlined above can be explained in terms of a magnetic field which is of the order of 5×10^{-6} oersted. Local regions of higher magnetic field are required to produce the observed intensity of radio emission in the disc, however. Because of the importance of knowing the strength of the galactic field, the Zeeman experiment is being continued at Jodrell Bank in an attempt to reduce the level of detection to 1 to 2×10^{-6} oersted.

THE RISING THREAT FROM ANIMAL DISEASES

K. V. L. KESTEVEN

Losses from animal diseases are mounting rapidly as they invade areas never before affected. International action on an unprecedented scale is going to be necessary to keep them from spreading further and eventually stamp them out.



The spectacular epidemic of African horse sickness in the Near and Middle East and the outbreak of African swine fever in Spain and Portugal are focusing worldwide attention on the growing threat to all countries of invasion by animal diseases that were originally confined to regions thousands of miles away.

During 1960, the countries stretching from Turkey to India lost between 200,000 and 300,000 horses and mules from horse sickness, a disease that was practically unknown outside Africa until 1959. It was probably introduced to the Near East region via the Persian Gulf early in 1959 and carried by nomad herds into Iran, Afghanistan and Pakistan where it flared up in the autumn of that year. By mid-1960, practically half of the 200,000 horses in the southern part of Iran had been lost and a German veterinarian travelling through the infected area described "battlefield scenes" of dead and dying horses all over the Middle East. The disease was reported in India in 1960 and then swept rapidly northwards and westwards to Iraq, Turkey, Syria, Cyprus, Lebanon and Jordan. It has come to a temporary standstill as a result of the destruction of the insect vector by winter frost, but all the countries that border the Mediterranean plus others in Europe and the U.S.S.R. are threatened by the possibility of a new outbreak this coming spring.

Although it is not feasible to vaccinate each of the 13 million horses and mules in the areas infected with African horse sickness, there is at least a vaccine available which can be used to combat its spread. This is unfortunately not the case for African swine fever. Although the virus causing the disease has been identified, no vaccine has yet been developed.

More than 120,000 sick and suspected pigs were slaughtered in Spain last year, resulting in an estimated loss of 500 million pesetas (£3 million). The Spanish Government has already paid out more than a fifth of this amount to indemnify farmers for the slaughter of their animals and implement the very complicated sanitary measures which are being enforced to prevent the disease from spreading further. Portugal also had a serious outbreak last year requiring the slaughter of some 16,000 pigs.

African swine fever appeared in Portugal for the first time in 1957, was eradicated after four months by slaughtering all the animals on the contaminated farms, but then reappeared in 1960. Spain had its first outbreak last year in the Province of Badajoz from whence the disease spread very rapidly because of the exceptional susceptibility of the animals to the virus.

AN UPHILL STRUGGLE

It took several centuries to establish control over epidemics of human diseases such as smallpox, plague, yellow fever, etc. This was achieved mainly through mass vaccination, constant medical checking, enforced quarantine regulations, and permanent medical vigilance. Man has not yet established similar control over animal diseases and, in fact, is not fully aware of the need to do so. The great majority of people in the world do not realise that their health and their daily food largely depend on the health of domestic animals. For instance, some control has

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been established over "sleeping sickness" in man but the same types of disease in animals in Asia and Africa still prohibit development in vast areas of potentially useful agricultural land.

The Food and Agriculture Organization of the United Nations is providing whatever assistance it can on these problems. It has helped the countries infected with African horse sickness to organise control of the disease, notably by arranging for supplies of vaccine from South Africa and by assisting in the establishment of vaccine production units in collaboration with the Onderstepoort Laboratory of South Africa. The Near Eastern and Asian Countries have already brought their vaccine production up to 200,000 doses a month

African horse sickness, showing characteristic swelling of the eyelids. *(FAO, Rome)*

—120,000 in Teheran, 50,000 in Cairo, 10,000 in Turkey, and 20,000 in India. Vaccine production will soon get under way in Pakistan, Afghanistan, and Iraq.

The use of white mice for the production of the vaccine presents one of the major difficulties. About 700 mice are required for 5000 doses. None of the institutes in the countries concerned has raised laboratory mice on a large enough scale and there are relatively few countries in the world where they can be obtained in sufficient quantity. Large numbers have been imported from the United States, the United Kingdom, Germany and Italy but these very often did not ship well. An FAO specialist in laboratory animal breeding has, consequently, been sent to the countries threatened to assist them in raising their own mice.

At an emergency meeting held in Paris in January, representatives of thirty-six countries agreed on a co-operative plan to keep the disease from spreading which involves the immediate organisation of a mass vaccination programme by the FAO in those countries on the fringe of the infected zone to form a *cordon sanitaire*. Turkey, Greece, Bulgaria, India, and Eastern Pakistan are to act as "buffers" to prevent the further spread of the disease in Europe and the Far East. The U.S.S.R. said it would begin vaccine production and immunise equine populations in areas adjoining infected countries. Delegates to the conference also called for further research on the problem of contamination via traditional and other means of transportation. Air transport, for instance, may have played a role in the spread of African horse sickness. FAO and OIE (the International Office of Epizootics) were requested to work with ICAO (the International Civil Aviation Organization) in advising on the control and disinfection of planes, cargo, and passengers at the airports of the countries infected and at the airports to and from which they fly.

Mouth lesions due to foot-and-mouth disease. *(Photoreporter, Rome)*

The Paris conference also took up the problem of African swine fever. Since an immunising vaccine has not yet been developed, the only major control measure available is mass slaughter of the affected and in-contact pigs. Experience in the Badajoz area of Spain has shown that the spread of this disease is so rapid, the discovery of infection must be followed immediately by "preventive slaughtering" throughout the surrounding area, sometimes out to distances of 10 km. The disposal of carcasses raises very serious problems. Special teams have been organised to slaughter the animals and then burn them or bury them in quicklime. In the 1960 control campaign, some of the trenches in which they were burned contained as many as 1600 carcasses.

The pig industries in both Spain and Portugal have been seriously affected by the drastic control measures taken by the authorities. Agricultural fairs, markets, and the transport of pigs have been banned, farmers and personnel employed on infected farms have been prevented from leaving their holdings and villages, the re-stocking of infected farms has been prohibited for at least six months, and the export of pigs and pig meat have been stopped. Apart from causing enormous economic losses, the present situation may reduce the protein intake of the people of both countries considerably as more than 50% of the meat consumed by the poorer classes is pork.

Virus of foot-and-mouth disease. 30,000×. *(Research Institute for Animal Virus Diseases, Pirbright)*

Veterinary services in both countries have traced the source of contamination to the town garbage used to feed the animals. In most cases, the outbreaks have actually started in the vicinity of urban centres where pig breeders use large quantities of such refuse. Spain and Portugal have now imposed strict control over the disposal of garbage; it must now be dumped at remote points or, where this is not possible, burnt or disinfected. The police have orders to shoot stray cats and dogs as these animals may carry the virus over long distances; gamekeepers have also been instructed to shoot wild boars that have become infected.

There is a danger that other European countries might become infected during the coming year, for the strict measures taken by the Portugese and Spanish authorities cannot prevent some movement of pigs and meat over the French border by workers, tourists, gipsies, and even smugglers. The problem has now become a matter of international concern and FAO is co-ordinating the effort to control the disease.

LOSSES FROM OTHER ANIMAL DISEASES

The economic losses from other animal diseases is staggering also. In Burma, during the last world war, nearly a million cattle were lost through rinderpest. Since most of these were ploughing and draft animals, the farmers were deprived of the power they needed to cultivate their land, children were deprived of milk, and there was a shortage of dung fuel for heating and cooking. Burma lost the whole of her annual export surplus of 3 million tons of rice which not only ruined her economy but brought the threat of famine to neighbouring Bengal.

The 1951–3 epidemic of foot-and-mouth disease in Europe cost £150 million. Five hundred outbreaks in Great Britain alone during 1951–2 cost the country £2,500,000 in slaughtering and compensation, and another costly epidemic occurred only recently.

Mastitis costs the British dairy industry some £10 million a year and that of the U.S.A. about £75 million a year although the incidence of the disease is now only 10% compared to the 30% of twenty-five years ago.

A report prepared by the OEEC in 1952 put the total animal loss in Western Europe at 15% that year—about £600 million—and this in one of the most advanced agricultural regions of the world. In the U.S.A., losses incurred from livestock diseases, parasites and insects are estimated to be about $2·7 billion (about £1000 million) annually.

Norris E. Dodd, former Director-General of FAO, has pointed out that the elimination of the blood-sucking intestinal parasites of domestic animals would result in a sufficient increase in food to more than satisfy the needs of all the deficient areas of the world. The infestation of a sheep's intestines by 1500 female worms causes a daily loss of blood of well over 100 ml. per sheep, according to Australian investigators. Well-fed sheep could survive this loss but poor grazing or infection by another disease usually kills sheep that are suffering from intestinal worms.

Present losses from lung worm diseases are estimated at £3 million yearly in the United Kingdom. Protozoal diseases caused by mono-cellular parasites also take a very heavy toll of livestock. Newcastle disease—a virus disease in chickens—is one of the most spectacular killers and has caused up to 100% mortality in infected flocks. Only the slaughter of hundreds of thousands of chickens or very extensive mass-vaccination campaigns have prevented decimation of the poultry stock of many countries over the last twenty years or so.

Man's struggle against animal diseases has been considerably complicated by air travel. Long sea journeys that often took several weeks used to allow time for symptoms of infectious disease to develop; with the advent of air transportation, the time taken by a trip between widely separated points seldom permits the development of telltale symptoms. Furthermore, virus diseases—the most dangerous of all—may be carried by human passengers; it is possible that aeroplanes have transported the insect vectors responsible for the present outbreaks of horse sickness. A virus disease in sheep, called bluetongue and considered enzootic only to certain areas of South Africa, has suddenly spread to several continents. In 1949 it was found in Cyprus, in 1951 in Israel, in 1952 in Texas, in 1953 further west in the U.S.A., in 1956 in Portugal, and in 1958 in Spain. Nobody yet knows how this disease broke out of South Africa. Strict control measures and quarantine regulations will have to be enforced internationally if man is to control epizootics.

ANIMAL DISEASES A THREAT TO MAN

Many people do not realise that it is possible for human beings to be infected by a number of animal diseases. Psittacosis, a disease of turkeys, pigeons, and parrots, can be transmitted to man. Rabies can be contracted from dogs, cats, and wild carnivores and anthrax from cattle by the consumption of infected meat, and the handling of hides, skins, feedstuffs, fertilisers, carcasses, wool, and so forth. Brucellosis, a bacterial disease, can be transmitted to human beings directly or through the consumption of milk from infected cows, goats, and sheep. Salmonellosis, a paratyphoid infection, can be contracted from infected eggs, milk, meat, vegetables, and fish.

Cattle are the main source of one type of tuberculosis found in man. A great number of parasitic diseases, including those caused by tape and round worms, bacteria and protozoa, affect both humans and animals.

These few examples clearly illustrate the urgent necessity for closer collaboration between veterinarians and medical authorities. Generally speaking, a considerable improvement has taken place in this respect, particularly in slaughterhouse control in urban districts, but there is still an urgent need to improve the health conditions of both animals and humans in rural areas where epizootics and consequent epidemics are a permanent threat.

The human race is increasing so rapidly that the present world population of 3000 million is expected to more than double during the next forty years. Half or more of the people on the Earth today are inadequately fed, lacking, in particular, animal protein. If the supply of animal products is to be increased by 300% by the year 2000—the estimated minimum requirement—man must establish effective control over animal diseases. This can only be done by setting up veterinary services in the countries which now lack them, strengthening the services in the other countries, and establishing effective international co-operation and co-ordination. Much has been done towards this end by FAO but the total effort made so far has not prevented the present epidemic of horse sickness nor has it eradicated foot-and-mouth disease from Europe. As each new outbreak shows, there is much work to be done, particularly in establishing effective co-operation between governments and veterinary authorities. Only by such international effort will man be able to control and perhaps ultimately eradicate animal diseases.

MASS FIRES FOLLOWING NUCLEAR ATTACK

A. BROIDO

The fire damage possible during a nuclear attack is rarely examined. This article gives a picture of the awesome destruction that may be expected from this quarter and the fire-control action that can be taken before and after an attack.

In the United States, the first analyses of the damage produced by nuclear detonations all took the view that such weapons produced their awesome results primarily as a consequence of the blast wave. Further investigation indicated that heat effects might well contribute more damage for greater distances and with greater production of casualties than any expected blast effect. However, before the heat hazard could receive the attention it deserves, it was again relegated to a secondary position by the sudden recognition of the large area of involvement and the fearful loss of life that may result from radiological effects.

Recently, fire effects of nuclear attacks have again come into the limelight. For example, during the Holifield Committee hearings on "The Biological and Environmental Effects of Nuclear War", considerable testimony, some of it misleading, was given on the heat and fire consequences of an assumed attack. Thus, a realistic appraisal of these fire effects is in order. This article attempts to present such an appraisal, without glossing over the disastrous consequences which may occur, and yet without exaggerating a problem which is bad enough if considered conservatively. Although extensive damage will result whenever mass fires form, a brief review of the process of fire ignition by thermonuclear attack and the characteristics of fire spread from the original points of ignition suggests certain fire control measures which can be taken to minimise the over-all effects.

FIRE EFFECTS OF NON-NUCLEAR BOMBS

By the end of World War II, it was generally recognised that fire effects are responsible for the greatest damage in a strategic air war.[1] This recognition was, however, far from instantaneous. As early as 1931 a German fire engineer, Hans Rumpf, wrote a book[2] which spelled out the role of fire in the destruction of cities in a future war, but his book was suppressed in Germany and ignored by the British and U.S. air forces. Even as late as February, 1945, the small-scale incendiary attacks which were attempted against the highly vulnerable Japanese cities resulted in little damage compared to an equivalent high explosive attack and tended to conceal the great potential of fire raids. Only after a successful large-scale incendiary raid on Tokyo, was it recognised that to be effective, such attacks should be on a scale "sufficiently great to overwhelm the civilian and professional fire fighters, exceed the water supply available, and create such intense heat that fires would progress virtually unchecked until they reached open spaces."[3] In other words, it is the formation of a widespread conflagration that gives fire the greatest potential as a destroyer of life and property following an air attack.

Before World War II, several cities in Europe and in the United States were destroyed by fire. The difference between those fires and wartime fires like the one at Hamburg following the attack of July 27–28, 1943, is vividly described by Rumpf.[4]

In the following night, the sixth, an even heavier attack, caused the last organised defence effort to collapse. The Chicago and San Francisco fires and other great fires which have been reported by contemporaries in terrifying, fantastic, and horrifying images must pale before the size and uniqueness of this Hamburg fire. There were 250,000 dwelling units completely destroyed out of 556,000—40,000 people had lost their lives.

Moscow had burned five days in 1812, the old city section of Hamburg four days in 1842, and San Francisco three days in 1906. Now the cities were being totally enveloped with fire and burned to the ground in a matter of hours. The only things remaining were broad fields of rubble, hollow buildings, empty façades of deserted streets of a ghost town—lifeless, illusory settlements. The burnt city lay like a wasteland, full of bricks, rubble, dust, and old iron. Over an expanse of several square miles lay the crushed and charred ruins and only here and there could be seen, still standing, a five-storey building or a single-house block. Up to this time, only the blind fury of nature had been able to wreak such destruction.

Before World War II was over, such total devastation had been inflicted a number of times.[5]

EFFECTS OF MASS FIRES

Mass fires of the type to be expected in the event of nuclear attack consist of two types—fire storms and conflagrations. The awesome conditions resulting when such fires occur have been described by Rumpf[5] in his account of the fire storm which followed the raid on Leipzig:

> Such a species of natural phenomenon as this can alter the properties of the atmosphere so that organic life is no longer possible therein and ceases. We have become accustomed to calling this phenomenon a "fire storm". The single fires join, the heated air shoots upwards as if in a giant chimney. The fresh air, sucked and rushing along the ground, creates a hurricane which in its turn fans the smaller fires and draws them into its course. The effects of such a hot column of air from a giant torch over a burning city were felt by fliers up to 13,000 ft. in the air and described as stormy and unpleasant. The only possible comparison is with the storms of the tropics at the peak of the wind scale. Our latitudes do not know the strength and devastating effects of such hurricanes.

Whoever has not himself experienced a fire storm will find it difficult to get a true picture from a description. At its edge are the conditions of a heavy storm. The roofs of trucks fly

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off, people's coats are pulled over their heads, those not standing firmly are knocked down. Approximately two and a half miles from the edge of such a fire, a weather station has measured a wind velocity of 34 m.p.h. which increased rapidly as one neared the fire area.

At irregular intervals squalls arise which strengthen the impetus of the storm. There is swirling, splintering, and crackling everywhere; even from the buildings and street fronts spared by the fire. The resistance of the building sections, calculated up to 30 lb./sq. ft., no longer suffices, a sign that a storm of 75 m.p.h. has been exceeded.

Farther in, life is practically impossible outside of protected buildings. Strong trees fall to the earth with splintering trunks, young trees are pressed to the earth like twigs. Hamburg lost 70,000 of its 100,000 street trees in this manner.

Motion is possible only by crawling, and even that is difficult and dangerous. I remember how firemen trying to arise were thrown down and whirled away until they finally were left lying with broken limbs in some sheltered spot. We had terrible casualties. Again and again men were actually hurled into the air. The driver of a fire truck was lifted out of his vehicle and thrown to the pavement before my eyes. He died of a fractured skull that same night. We tried to send an automobile sedan across an open square from the protection of a garage. It was seized by the wind and, tumbling over and over like a box, was carried off with its occupants. The basement of our fire station was like a dressing station for troops in the front lines.

Fire storms of the type described by Chief Rumpf are expected to follow rapid ignition of large areas in the absence of a strong ground wind. Since the fire winds blow towards the centre of the fire, there is usually little fire spread beyond the area originally affected. A conflagration, on the other hand, is a great fire which moves along the ground under the influence of strong winds. The column of rising hot air, once it has been established, slants appreciably to leeward and large numbers of fire-brands shower upon the leeward region. Also, the higher the wind velocity, the more the column leans and the closer the hot and burning gases approach combustible materials on the ground.

The chief characteristic of the conflagration, therefore, is the presence of a fire front, an extended wall of fire moving to leeward, preceded by a mass of preheated turbid burning vapours and by a large number of spot fires ignited by the fire-brands. Since the fire continues to spread in a downwind direction until it runs out of fuel, the total destruction by a conflagration may be much greater than that by a fire storm. However, beyond the area of original involvement, the characteristics of the fire (particularly in such factors as rate of spread and effect of firebreaks) become more like those of the large urban and forest fires of the past. Although some such fires have consumed thousands of square miles over a number of days, even without fire-fighting they have reached natural barriers and have burned out—leaving vast areas unscathed.

IGNITIONS BY THERMONUCLEAR DETONATION

A thermonuclear detonation can start fires both by primary heat effects (ignition by visible light and infra-red radiation given off by the fireball), and by secondary blast effects (overturning of stoves, short circuiting of wires, etc.). Since fire can spread rapidly, essentially the same degree of damage could very well result from fires produced by either effect alone, and this has led to considerable confusion concerning the effectiveness of heat radiation in the production of fires. Additional confusion has resulted from the inability to produce sustained ignition by short pulses of heat radiation in many fuels normally considered highly inflammable. For example, a sound wood surface exposed to a short pulse of heat will char, perhaps quite badly, and flames may often be produced during the application of radiant energy; but the temperature throughout the fuel will not be raised sufficiently to sustain ignition, and any flames which are started die out immediately after the exposure. On the other hand, such pulses of heat easily ignite many kindling fuels—thin materials such as dried leaves or shredded newspaper, or material like rotten wood which on the macroscale appear to be solid but which may be considered as consisting of an extended network of thin, porous inflammable material. Fires which originate in such kindling fuels may then ignite adjacent denser fuel.

The critical ignition energies for the various kindling fuels depend upon such factors as (*a*) the relative humidity and consequent moisture content of the fuel, and (*b*) the duration of the heat pulse (which lengthens with higher weapon yield). The heat energy irradiating an object some distance from ground zero depends upon such factors as the weapon yield, the height of burst, and the visibility of the atmosphere. The quantitative influences of these various factors are discussed elsewhere;[6, 7, 8] but by way of illustration, on a very clear dry day a ten-megaton nuclear airburst could produce heat ignition out to distances greater than thirty-five miles. At these distances, blast effects would be limited to window breakage and other such minor damage. If kindling fuels were exposed throughout the entire region, the circular area of instantaneous heat ignition would be almost 4000 square miles and would include large regions that would escape serious fallout effects from an equivalent surface burst.

Any solid opaque material, such as a hill, or a tree, between the fireball and the target will shield the target from heat radiation. However, a hazy atmosphere does not provide as much protection as has frequently been thought, because the dust particles in the air scatter (reflect) rather than absorb the heat radiation, and although the radiation is diffused it can still arrive at the target. Furthermore, unless a solid shield completely surrounds the target, it will not be entirely effective if a large portion of the heat radiation received has undergone "scattering" (reflection) and arrives from directions other than from the point of burst.

FIRE SPREAD

Since an ignition point is of concern only if contiguous fuel insures the formation of a growing fire, the development of a mass fire following nuclear attack depends not only on the presence of kindling fuels, but also on the presence and spacing of all combustible material in the area. Consequently, fuel factors which affect susceptibility in conventional fires are also of concern in assessment of vulnerability of heat.

Perhaps the most important factors influencing the spread of fire in an urban area are building density, defined as the

ratio of projected roof area to total ground area included in a particular region, and the size of the area included in each building density category. The three density categories that have been recommended[9] for use in fire analysis of urban regions are (1) 0 to 5%, (2) 6 to 20%, and (3) more than 20%. The 0 to 5% category comprises areas in which fires do not generally spread beyond the buildings in which they originate. If these areas are sufficiently large they constitute a major firebreak. The 6 to 20% category comprises areas in which fires may spread beyond their point of origin, but are not expected to merge and form mass fires. In areas with more than 20% building density, mass fires may develop, provided the density extends over an area of at least a square mile. Over smaller areas, mass fires are unlikely even though the combustible contents of the area are completely burned out; but in considering such areas, the spread of fire from grass, brush, and woodland areas to additional urban complexes cannot be overlooked.

Considerable information has been obtained concerning fire spread from the many wildland fires which occur annually in the United States. Although ignition and spread of such wildland fires have been found to be highly dependent upon weather conditions, weather does not influence fire spread in urban complexes as much as has been frequently assumed.

For example, if one considers the danger from indoor ignition, one finds that the seasons considered safe in the case of forest fires are frequently the most dangerous in the case of nuclear attack. Thus, in the northern part of the United States the winter months are considered as a period of safety from forest fires. Yet during these months most buildings are heated; where humidifiers are not in use, the humidity conditions indoors are dangerously low, perhaps lower than they ever are outdoors; and the hazard from fire starting indoors is extremely high.

Even for outdoor fuels, high humidity during the period preceding the attack is important only in the beginning stages of a fire. However, kindling fuels are quite thin and respond quite rapidly to changes in humidity. Thus, a very short period of sunshine, even after the heaviest rains, will dry out many of these fuels. In fact, the energy in the heat pulse itself can dry out and then ignite the kindling fuel at only a slightly higher energy level than would have been required had the fuel been dry. Once a fire is well established, it can readily overcome the retarding effect of moisture in heavier fuels. In fact, studies conducted during the last war indicate that even when rain was falling during conventional fire bomb attacks, the damage produced averaged only 20% less than that produced under favourable weather conditions.[10]

FIRE CONTROL

In this article, the term "fire control action" includes all steps taken before or after a nuclear attack which will tend to minimise the effects of such an attack. Appropriate fire control action may be directed along three lines, namely, (1) reduction in number of potential ignitions, (2) provision for isolation or rapid extinguishment of ignitions to prevent formation of serious fires, and (3) minimisation of fire spread potential should large-scale fires be produced. Incidentally, anyone who feels that, if any fires should be produced in an attack, the safe construction practices in the United States will keep its cities from burning as readily as did the highly combustible Japanese cities may be disillusioned upon learning that the structures that make up our major cities range from more than 99% combustible construction in San Francisco to a low of 96·4% combustible construction in Washington, D.C.[11]

Effective fire control steps which may be taken range from very simple ones, readily put into effect, to complex and costly ones. For example, reduction in the number of potential ignitions may be accomplished by removal of kindling fuels. The elimination of wood as a construction material and its replacement by concrete, bricks, and metal, of course, is one step (a rather expensive one) in this direction, but continuous upkeep of existing wood structures to prevent the exposure of rotting wood is a cheaper step in the same direction.

The effectiveness of eliminating kindling fuels in reducing ignitions was rather strikingly demonstrated in a civil defence experiment during Operation *Upshot Knothole*, the atom-bomb test series conducted in Nevada in 1953.[12] Three mock-up frame houses were constructed at identical distances from the ground zero and exposed to one shot during that operation. One of the houses was well maintained and had a painted wood siding and a clean yard. Another house had a clean yard but had unpainted, weathered, decaying siding. The third house was poorly maintained and was surrounded by adjacent dry weeds and trash. After the detonation, the first house showed only mild scorching and was not significantly damaged. The second house suffered smouldering ignition which later burst into flames and consumed the building. The third house was ignited and quickly consumed.

If kindling fuels cannot be eliminated, shielding of such fuels from a heat flash is an effective means of eliminating the danger. Thus, ignitible trash in covered metal containers will not be ignited by a heat flash. Covering windows in existing structures or constructing windowless buildings can minimise ignition of internal kindling fuels. Shielding of large regions by smoke-screens may effectively reduce vulnerability to heat, wherever the smoke is dense enough to reduce the energy delivered to levels below critical, provided (1) the screen can be laid down before the detonation, (2) it is large enough to minimise the probability of fire spread to the covered area, and (3) it is sufficiently low so as to not greatly increase the heat reaching the target as a result of downward "scatter" from smoke above the fireball.

Once the number of potential ignitions has been reduced to a bare minimum, the next major step is to plan and train for the elimination of these small ignitions before they can grow into serious fires. Those ignitions which occur remote from any large combustible complex may be allowed to burn out with minimal over-all effect. Since all other ignitions must be extinguished promptly (at Hiroshima the initial fires had merged to mass fire proportions in about a half-hour), the job of fire-fighting cannot be left to a fire department which proceeds with a small number of major pieces of equipment to the scene of each fire after it has been reported. Rather, a first aid type of fire-fighting must be adopted. Everyone must be taught to act promptly after

the immediate effects of a detonation are over and to try to extinguish all such incipient fires within his immediate reach. In the first few minutes many of these fires can simply be stamped out. Small fire extinguishers, readily available, or even buckets of water or sand are extremely useful in these early times. If each person extinguishes enough of these small fires early enough, perhaps few will grow sufficiently large to require the services of a professional fire department.

It is important to spread out the tools which must be used to combat fires and to take considerable care to insure that the facilities are properly located and truly independent. For example, many urban areas utilise a single water supply. A break in the water main at one place would completely eliminate the water supply to such an installation. Even if several independent supplies feed into one common system, the entire supply may be wasted if it is possible to cut off a part of this system. Thus, the official report of the U.S. Strategic Bombing Survey[13] concerning the bombing of Hiroshima contains the following paragraph:

> The water reservoir, which was of reinforced concrete and earth-covered, was undamaged; it was nearly two miles from the blast centre. However, 70,000 breaks of pipe connexions in buildings and dwellings were caused by blast and fire effects. No sub-surface pipes were crushed and no leaks resulted from blast as a direct cause, though several leaks in underground mains resulted from falling debris. Pressure in the city centre dropped to zero because of the connexion breaks and the damage to a 16-in. and a 14-in. water main where they crossed damaged bridges.

Even after everything possible has been done to minimise the probability of formation of large fires, steps should be taken to minimise the effects of these fires should they occur. Natural firebreaks must be utilised to provide the utmost in fire protection (whether or not they ultimately prove to be effective). Highly combustible regions must be eliminated as soon as possible.

Finally, considerable research and training effort must be expended on techniques for the fighting of such mass fires. That fire-fighting is not completely hopeless has been indicated by Chief Rumpf[14] in his description of the Hamburg fire:

> Often the fire stopped only when it found no more fuel—even if the battle against the fire was hopeless in the centre of the gigantic area fires, on their periphery, and in countless individual locations; gradually here and there, the fire-fighting began to show results. Individual structures, house blocks, lines of streets, and whole districts were saved. These would certainly have been destroyed had it not been for the efforts of the fire-fighting forces. Thousands and tens of thousands of families here, in the other cities, are today indebted to the fire departments for their homes—the safety of their saved dwellings. So, taken as a whole, the efforts even in Hamburg have not been completely in vain.

CONCLUSION

The over-all fire effects following nuclear attack will most certainly depend upon the number and distribution of ignitions produced; the weather, fuel, and topographic features which influence fire spread; and the fire control action taken, both before and after the attack.

In a recent paper exercise involving a simulated attack on the western part of the United States, the author assisted in the assessment of fire effects of the simulated strike. The assigned effects varied greatly with location. On the basis of extreme weather and fuel conditions in the Los Angeles area, it was concluded that the fire would burn at will from ocean to desert. In the San Francisco area, the fire was held to 200 square miles (unfortunately, including most of the urbanised Bay Area). However, in Portland, Seattle, and a number of other points, a combination of favourable circumstances (on paper, at least) kept estimates of fire damage to a fairly low level. Further, careful analysis of the results of this exercise indicated the much greater reduction in effects which would have been possible had additional pre-attack fire control action been taken.

Although past attempts to stimulate study and action have been most discouraging, it is hoped that more widespread distribution of information on the fire consequences of nuclear attack will help combat the situation so aptly described by Horatio Bond, Chief Engineer, National Fire Protection Association.[15]

> We have been living, since World War II, in an atmosphere which in some ways is a little hard to explain. Many of the lessons of the last war and of the A-bomb and H-bomb are perfectly plain. They pose to everyone some very serious problems. Solution of many of these problems means radical change in how we build our cities and how we run our fire departments. Rather than face the necessity for making any of the obvious changes, most citizens and officials of government—federal, state, and local—have preferred to ignore the problem of modern war. Some problems, if ignored long enough, will go away. I wish the same could be said of these.

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THE INTERNATIONAL INDIAN OCEAN EXPEDITION 1959–64

ROBERT G. SNIDER

As a result of a unique set of conditions, the Indian Ocean is possibly the most productive of all the oceans, biologically. Virtually nothing is known about it at the present time but it will undoubtedly become the best understood of all the major bodies of water after this multi-nation effort.

Over the next four years, a fleet of ships carrying scientists with their highly specialised equipment will be sailing in the Indian Ocean on new voyages of discovery, bringing one of the last unknown areas of the globe under intensive scrutiny. More than forty vessels with scientists from over twenty countries will cruise the waters of this vast body of water in a joint effort that has come to be called the International Indian Ocean Expedition. No ocean has yet received so much attention.

The Indian Ocean covers one-seventh of the surface of the earth and the countries bordering on it hold 25% of the world's population. Although this vast area is less known and less understood than any of the other oceans, there is sufficient fragmentary evidence to indicate that biologically it may be the most productive one. The international plan calls for a study of the entire system from below the bottom, through the water itself (with its biological contents and its physical and chemical characteristics), through the boundary between the sea and the atmosphere, and on upwards to the upper atmosphere. The scientific disciplines brought into play will include geology, geophysics, bathymetry, oceanography, biology, and meteorology.

One of the major objectives is the development of an oceanographic science in the Indian Ocean area with the associated institutions necessary to support it. The Expedition offers an opportunity for training in the marine sciences to nationals of the surrounding countries under the guidance of experienced scientists from outside.

The planning for this major oceanographic event has been in progress since 1957 under the aegis of SCOR, the Special Committee on Oceanic Research of the International Council of Scientific Unions. Late in 1960, UNESCO agreed to co-sponsor the Expedition.

The first question that usually arises in the minds of many people is:

How does the Indian Ocean differ from other oceans and of what significance is this?

The Indian Ocean has several unique features. Outstanding is the 180° reversal of the prevailing winds twice a year in its upper part at the onset of the northeast monsoon and the southwest monsoon. The monsoon wind reversal creates varying currents at different seasons of the year which, in turn, affect the entire oceanic circulation. As a result, there is on each of the four coasts of this ocean at some time of the year a wind setting up currents which create upwelling with a consequent increase in nutrient circulation. This plus the occasional observations of vast quantities of dead fish on the surface suggests that the Indian ocean may be one of the most productive bodies of water.

Equally unusual is the fact that this virtually unknown body of water is the sole major ocean which is open only at one end. It is fed at the closed northern end by the great rivers of the Middle East that run into the Arabian Sea and by those of East Pakistan, Burma, and India which carry fresh water and sediment into the upper part of the Bay of Bengal; cold water enters only from the Antarctic to the south. The currents of the Indian Ocean are ill-defined and there is great interest in whether an equatorial counter current exists similar to the ones found in the Pacific and Atlantic at considerable depths.

OBJECTIVES

The overall objective of the Expedition is to gain some understanding of the interaction between the earth, the sea, and the atmosphere.

Physical and Chemical Oceanography. The scientists associated with the project will try to find the answers to questions such as these:

1. How long does it take the winds to set up a current and how rapidly does a current deepen with time?
2. What proportion of the energy required to maintain an ocean current comes from the wind and what proportion from horizontal density gradients that are due to regional climatic differences?
3. How does internal friction and friction with the bottom influence the velocity-depth distribution?
4. What is cause and what is effect in the general circulation of the oceans?

A wide variety of observations will be needed to answer these questions. Almost every ship will cruise during both monsoons, measuring currents at the surface and at various depths, taking temperatures, and sampling the water for salinity and other characteristics at intervals of 10 to 100 miles. The major water masses will be defined and density layers described. The network of ship coverage planned so far is reasonably satisfactory for the region north of 40°S.: as the Expedition progresses, the gaps in the northern part should be filled in and observations in the southern part

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extended through co-operation with the Antarctic investigations.

Chemical analyses of water samples will throw light on these questions:

1. What is the distribution of plant nutrients and dissolved organic compounds in various parts of this ocean?
2. What is the effect of drainage water on sea water in a partly-closed basin?
3. How can one describe the circulation by Carbon-14 dating of the water?

Water samples will be analysed for oxygen, inorganic phosphorous, total phosphorous, silicate, nitrate, and trace elements as well as C-14.

Marine Biology. All ships will carry out a minimum biological programme by means of standard water sampling and the collection of specimens with various types of nets and trawls. The overall effort is designed to:

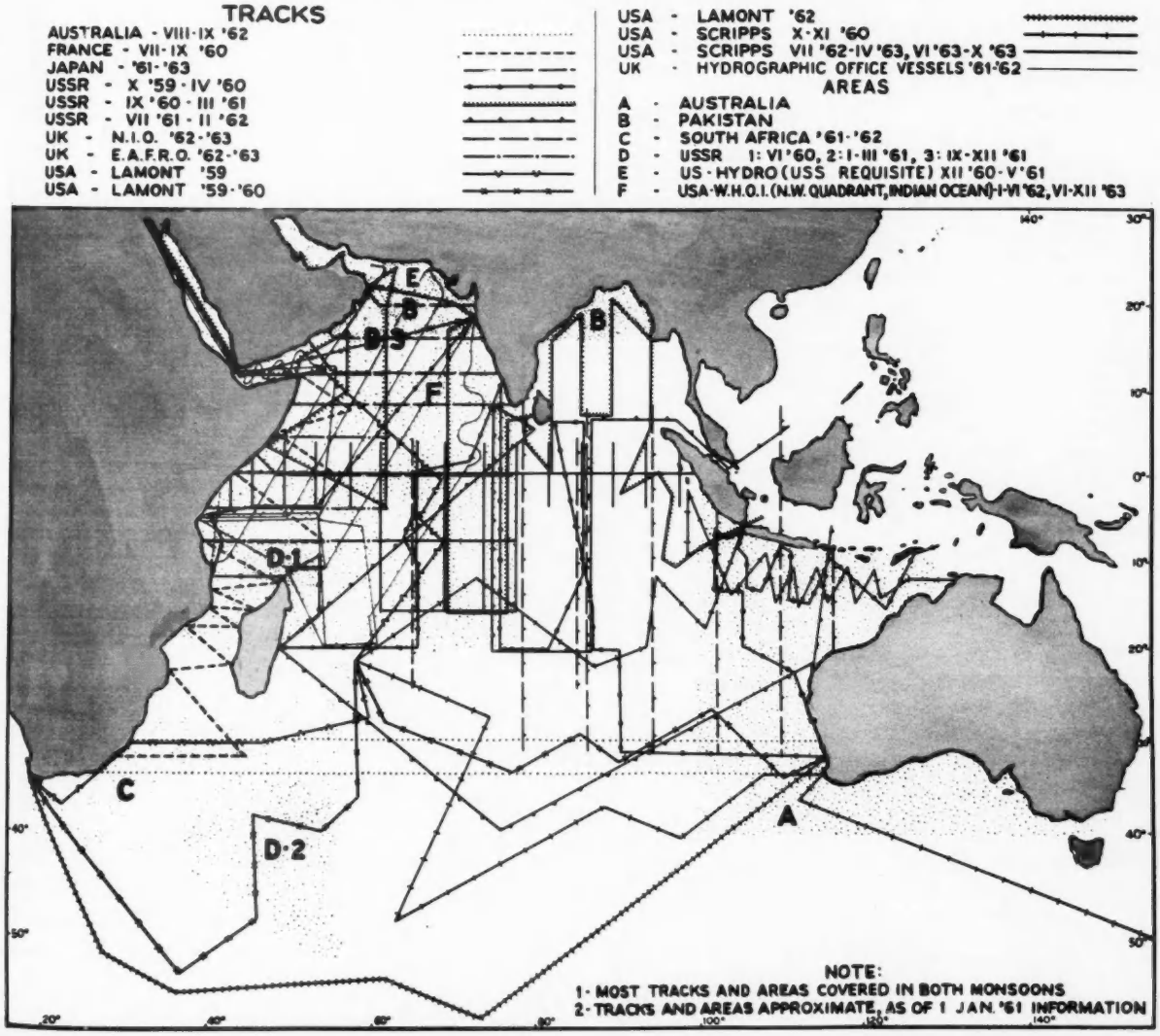
1. Study the three-dimensional distribution of plants and animals in the Indian Ocean.
2. Investigate the quantitative ecology of the plankton.
3. Collect as much information as possible about the fisheries of the Indian Ocean.

Some vessels will make biological oceanography their primary mission during part or all of a cruise. In addition to the minimum programme, they will concentrate on such biological phenomena as:

1. Coastal upwelling around the entire Indian Ocean.
2. The study of equatorial divergences.
3. The study of coral reefs and their surrounding environments.
4. The problem of massive fish mortality.
5. The special problems surrounding regions of convergence.

Marine Geology, Geophysics, and Bathymetry. The topographic features and geology of other oceans have been studied in some detail during the last few years but vast gaps still exist in the knowledge about the Indian Ocean. These gaps are now beginning to be filled in by the recent

CRUISES COMPLETED AND PLANNED 1959-1963


TRACKS
AUSTRALIA - VIII-IX '62
FRANCE - VII-IX '60
JAPAN - '61-'63
USSR - X '59-IV '60
USSR - IX '60-III '61
USSR - VII '61-II '62
UK - N.I.O. '62-'63
UK - E.A.F.R.O. '62-'63
USA - LAMONT '59
USA - LAMONT '59-'60
USA - LAMONT '62
USA - SCRIPPS X-XI '60
USA - SCRIPPS VII '62-IV '63, VI '63-X '63
UK - HYDROGRAPHIC OFFICE VESSELS '61-'62
AREAS
A - AUSTRALIA
B - PAKISTAN
C - SOUTH AFRICA '61-'62
D - USSR 1: VI '60, 2: I-III '61, 3: IX-XII '61
E - US-HYDRO (USS REQUISITE) XII '60-V '61
F - USA-W.H.O.I. (N.W. QUADRANT, INDIAN OCEAN) I-VI '62, VI-XII '63
A
B
B
C
D-1
D-2
E
F
NOTE:
1- MOST TRACKS AND AREAS COVERED IN BOTH MONSOONS
2- TRACKS AND AREAS APPROXIMATE, AS OF 1 JAN. '61 INFORMATION

cruises of the United States ships *Vema* and *Argo* and the U.S.S.R.'s *Vityaz*. A bathymetric chart of the Indian Ocean shows great distances between contour lines and a lack of detail which is characteristic of our knowledge of this area. Three general groups of problems require detailed investigation:

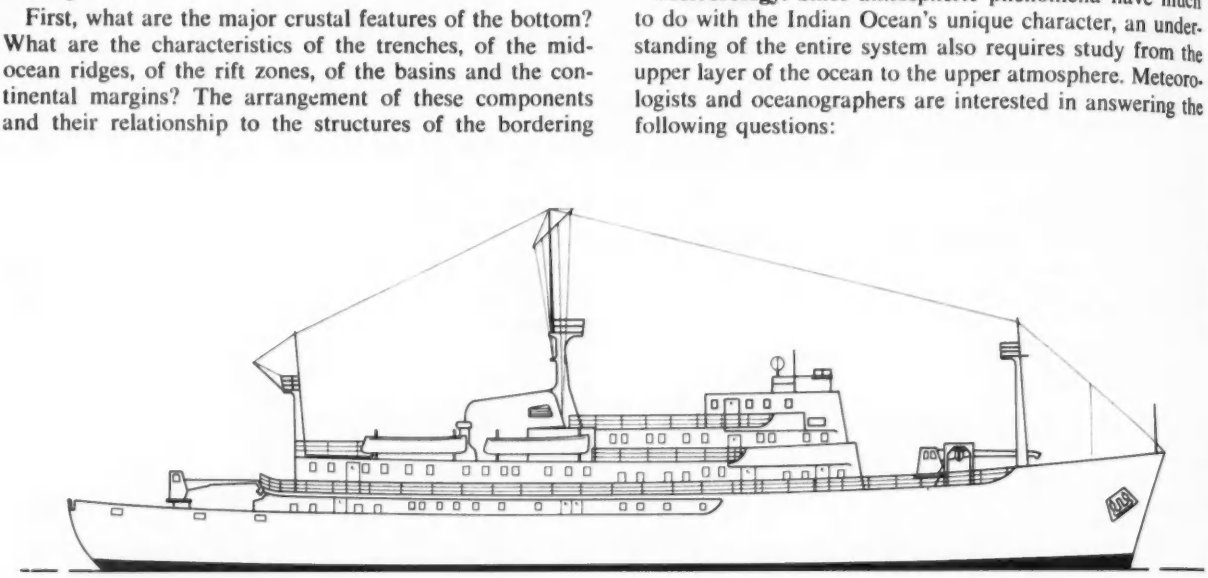
First, what are the major crustal features of the bottom? What are the characteristics of the trenches, of the mid-ocean ridges, of the rift zones, of the basins and the continental margins? The arrangement of these components and their relationship to the structures of the bordering continents are markedly different in the Pacific and Atlantic. Is the Indian Ocean an Atlantic or Pacific type ocean?

Next are the questions about the sedimentary processes and records. What is the relationship between the geophysical and sedimentary provinces? What is the significance of Dolomite in the area? What are and have been the biological processes occurring which may be revealed by cores and by analyses of the marine sediments? What are the mineral resources in the Indian Ocean which might be tapped from bottom deposits?

The third set of problems involve the boundary relations of the geological features in the Indian Ocean. We need a careful definition of the eastern, northern, and western margins, and a description of the general problems of boundaries within the various areas of this body of water. The islands in the Indian Ocean vary from coral to granite bases, with volcanic islands in the southern part. What will paleomagnetic records and other investigations show about the history of this ocean and the associated areas?

To obtain the answers to these questions, vessels in the Expedition will study bottom topography with precise echo sounders having an accuracy of one part in 5000. Some ships will examine the crustal structure of the bottom by making seismic tests. These cruises will not follow rectangular co-ordinates but will follow, rather, the known or likely variations in the bottom structure in order to reveal those particular features which are unique to it. The bottom will be sampled by taking deep cores periodically and by dredging at frequent intervals; underwater photographs will be taken also. At critical points, heat-flow measurements will be recorded and some ships will carry out magnetometric and gravimetric measurements.

Meteorology. Since atmospheric phenomena have much to do with the Indian Ocean's unique character, an understanding of the entire system also requires study from the upper layer of the ocean to the upper atmosphere. Meteorologists and oceanographers are interested in answering the following questions:



New oceanographic research vessel about to be constructed for the National Institute of Oceanography (U.K.)—one of the first of the new generation of research ships now being designed and built by the major maritime powers. About 260 ft. long and displacing 2800 tons, it will be completed early in 1962.

1. How can the large-scale atmospheric circulation of the Indian Ocean be described?
2. How can evaporation and vertical heat flux be determined over large areas?
3. What is the areal distribution of vertical flux of water vapour, heat, and momentum?
4. What are the local interface fluxes at the air-sea boundary?
5. What is the average energy transfer or heat budget for the atmosphere and the ocean?
6. How do we interpret satellite cloud photographs and infra-red measurements in terms of such meteorological observations?

The United States will probably undertake a substantial part of this phase with the assistance of nations bordering on the Indian Ocean. For this study, the existing meteorological networks will need to be supplemented by new island stations down the middle of the ocean and across the bottom of the Arabian Sea; several weather ships will be required below the Bay of Bengal to complete the ocean coverage. All of the fixed and floating stations will take observations from the surface to the upper atmosphere (including radio sonde and radar wind readings) and will be supplemented by specially-equipped aeroplanes, possibly a specially-equipped submarine, and meteorological buoys; high altitude observations will also be made with satellites. The objective of the combined oceanographic and

meteorological observations is to obtain a picture of the air-sea system in action on a broad scale over a period of time.

SPECIAL PROBLEMS

Navigation. Precise navigation is particularly desirable for bathymetric, geological, and geophysical work and for the study of currents. Unfortunately, the accuracy of celestial navigation is seriously affected by weather conditions and individual variations, and other systems are expensive for an area so vast. A number of alternative methods have been investigated, however, and one of these, involving the use of the United States' *Transit* navigational satellite, can provide an accuracy of 0·5 to 1 mile. After extensive tests of the system, the U.S. Navy has offered to lend a limited number of simplified receivers and computers to Expedition vessels but the delivery dates may be towards the end of the programme.

The existing *Loran A* and *C* are too expensive and could not achieve complete coverage and *Omega*, a very low frequency system, is unlikely to be operational in time. During the early phases of the Expedition, therefore, the participants will have to depend on celestial navigation and the *Decca* system although the U.S. is considering sun-trackers for daytime all-weather positioning for some of its vessels.

Training. The development of oceanography as a science which is integrated into the activities of the Indian Ocean nations is an objective that is as important as obtaining fundamental scientific knowledge of the area. To achieve this end, UNESCO, several nations, various intergovernmental agencies, and some private foundations will assist in advanced specialised training of the nationals of these countries.

Biological Collections. Without a new facility, biological collections will overwhelm the traditional centres of taxonomic analysis—the museums and universities. To alleviate this problem, plans are being developed to establish a biological centre at a convenient point in India, to be operated by India with substantial assistance from UNESCO and participating nations. Biological samples will be divided by the ships, half of each going to the centre for basic classification and analysis. The collection will serve as an Indian Ocean reference source and, after primary sorting, specialists in various biological fields will be brought in for final analyses.

The Expedition is the first full-scale effort to co-ordinate oceanographic and meteorological observations in a single oceanic system. The findings will be published in part as papers by individual scientists in professional journals and these will be issued later as a collection of reprints. An atlas describing the Indian Ocean's characteristics will also be published.

PRESENT STATUS AND PLANNING

The preliminary phase of the Expedition will be completed early this year with the conclusion of extensive cruises by oceanographic vessels of the Soviet Union, the U.S.A., France and Australia. The balance of 1961 will be devoted largely to consolidation of information and detailed planning, although several countries around the Indian Ocean will be making cruises in the course of their normal operations and vessels from Britain, the U.S.A. and the U.S.S.R. will be operating in the area. From mid-1962 through 1963 there will be an intensive effort by virtually all the participating nations, using ships, buoys, submarines, aeroplanes, satellites, and island and shore installations for tidal and meteorological measurements. No detailed plans have been laid out for 1964 as yet but they will be developed later on the basis of accruing information.

The preliminary plans were drawn up by an international working group that was set up by SCOR early in 1960 under the chairmanship of Dr G. E. R. Deacon, director of Britain's National Institute of Oceanography; Dr V. G. Kort of the U.S.S.R. was vice-chairman of the group. During this period, the Co-ordinator visited sixteen countries in various parts of the world to stimulate interest and determine the extent and nature of their participation. A minimum plan was developed at a meeting in Copenhagen last July when sub-working groups met to outline the scientific objectives of the Expedition, define the problems to be investigated, and agree on procedures and standards. IAMAP (the International Association of Meteorologists and Atmospheric Physicists), in response to a request, set up a working group to co-operate with SCOR on the definition of a meteorological programme. WMO (the World Meteorological Organisation) agreed to assist in the programme for obtaining synoptic meteorological information. Preliminary plans were laid for close co-operation with SCAR (the Special Committee on Antarctic Research).

Within the basic framework, national committees in the participating countries proceeded to draw up detailed national plans which are being co-ordinated through personal contact and the rapid exchange of preliminary documents. By mid-summer of this year—at least a year before the major effort begins—there should be a series of detailed national plans available. Several international meetings, including the Tenth Pacific Science Congress in Honolulu late this summer, will enable many of the nations to exchange information. The Honolulu meeting will also offer an opportunity for a direct comparison of field techniques among Australian, Japanese, Russian, and U.S. ships which are expected to be there.

Plans are now being laid for the establishment of logistic centres around the Indian Ocean area and for the provision of laboratory space at various institutions for local working up of research material. To help overcome the shortage of scientists and technicians, particularly in the countries bordering the Indian Ocean, training facilities will be expanded and new ones set up, and at least sixty scientists from these countries will be given the opportunity for advanced training in institutions outside the region. Such training is to be specially directed towards participation in the Expedition.

The international character of this project and its consequent impact on all oceanography is indicated by the current activity of the nations involved. The fundamental science developed during the Expedition will serve as a base for understanding the processes of this vast oceanic system on which applied sciences can build for the direct benefit of the large population of the Indian Ocean area.

STRAINING WATER OUT OF THE CLOUDS AT GIBRALTAR

G. W. HURST

For every 10,000 square feet of mesh erected vertically at cloud level, the water-short people at the Rock could get an additional quarter of a million gallons of fresh water annually—at a relatively low cost.

The ever increasing-demand for water at Gibraltar has always been a problem. The large-scale collection of rainwater was started during the early 1900s with the erection of enormous catchments on the side of the Rock and the construction of correspondingly large reservoirs inside the Rock. Catchments now cover an area of thirty-eight acres, the most efficient of them being made of corrugated iron sheeting.

Most of the rain at Gibraltar occurs during the winter months, between October and April, the total varying widely from year to year. In an average year, when the rainfall is thirty to thirty-five inches, about 15 million gallons are collected. Deep wells drilled more recently in the flat isthmus that joins Gibraltar to Spain provide an additional 25 million gallons annually. Water is also obtained by distillation (still relatively expensive), and purchased from outside; new oil tankers sometimes carry water out on their maiden voyages and, when there is a dire shortage, special ships are chartered to bring water from North African ports.

Gibraltar is, thus, an obvious place to try alternative methods for obtaining water. With the clouds around its summit (Figs. 1 and 2), it seemed ideal for an experiment on the direct removal of water from clouds.

THE UNIQUE CONDITIONS AT GIBRALTAR

Winds through the Straits and at Gibraltar itself are channelled so that they flow mainly eastward or westward. The peninsula, rising almost sheer on its eastern flank, lies across this flow. (The peninsula is about three miles long and three-quarters of a mile broad.) Westerly winds are more common during the winter and easterlies are more frequent during the summer. Called *levanter* by the local people, the easterly winds usually travel over a long fetch of the very warm Mediterranean and are therefore humid at low levels when they reach Gibraltar. The upflow over the Rock is sufficient on many occasions to cool the air and cause a cloud to form as a plume over and to the west of the Rock, as shown in Fig. 2, even when no other clouds are present. It is quite common, therefore, to see a pall of low stratus cloud covering the upper Rock. Of particular interest is the fact that this takes place during the summer —the dry half of the year when the storage tanks of the colony begin to run low. (The limited storage capacity unfortunately makes it impossible to take full advantage of a particularly wet winter.)

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G. 1. View of the Rock from
e south.
(RAF, St Eval)

THE EXPERIMENT

To find out if water could be taken directly out of these clouds, "catches" were designed to trap the droplets in the clouds as they passed by. These catches were made by mounting close metallic mesh of the mosquito-net type in a sturdy 3 ft. by 6 ft. frame (Fig. 3). Two types were tried, one with a single layer of mesh and the other with two layers separated by about 2 in. Some difficulty arose in finding a suitable location but the test was finally set up in a slight dip in the ridge of the Rock at Middle Hill, 1000 ft. above sea level. One advantage of this site was the location of a service unit nearby, the personnel of which were prepared to assist in taking observations. The frames were installed firmly so that they would stand up against the strong winds which are frequent (and desirable) in the Middle Hill gap where a venturi effect increases the flow. A rain gauge was placed between the two catches as a check on any contribution from rainfall.

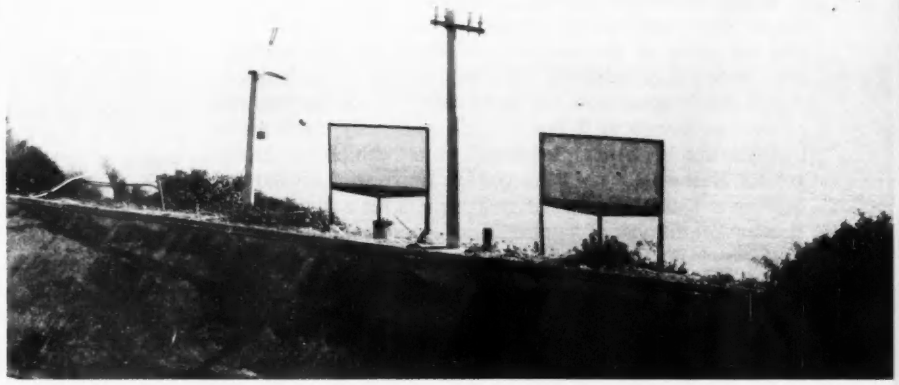
The experiment lasted about eight months. The amount of water collected depended on the wind speed, the time of passage of the cloud, and its density. The greatest yield obtained with the 16 sq. ft. of exposed mesh was about 1·25 gallons in an hour; this was during the winter with an unusually dense cloud. During the summer, the maximum rate of collection was 0·87 gallons/hr. There was little real difference between the yields from the single and double-mesh catches on most occasions, the lower efficiency of the former being compensated by the easier flow of air through it. Calculations showed that optimum ratio of mesh diameter to mesh spacing was 0·29 for the single mesh and 0·16 for the double. The mesh actually used had a ratio of 0·18. It was estimated that the use of a thicker mesh would have increased the yield from the single screen by about 10%. If the difficulty of shake-off could be overcome (for example, by partial baffles behind the frame), the single mesh should prove more satisfactory than the double, and cheaper as well. Theoretically, the catch can be increased by decreasing the wire size, but the wire in the mesh used—0·011 in. in diameter—was probably the finest that is capable of standing up to the strong winds.

FIG. 2. A view of the Upper Rock showing a plume of cloud, not quite low enough on this occasion to give much catch. The turbulent nature of the lower face of the cloud near the Rock can be seen.

RESULTS

The experiments showed that each sq. ft. of mesh should yield a minimum of 7 gallons of water during the summer or dry half of the year and 5 gallons during the winter or wet half, with an additional 8 gallons from rain during the winter—a total, at the very least, of 20 gallons/sq. ft. or a quarter of a million gallons from a catch of 10,000 sq. ft. The erection of screens at the Rock ridge of sufficient strength to withstand the high winds that frequently occur would be a problem but once erected they would provide a fairly continuous supply of water, particularly during the usual period of shortage, the only cost being the upkeep of the mesh.

FIG. 3. The experimental cloud-catching screens as seen from the west, with the Mediterranean in the background. The double screen is at the right.
(RAF, Gibraltar)



NEW INVENTIONS FROM AN OLD DISCOVERY

J. H. M. SYKES

The Hall effect—a scientific curiosity for about three-quarters of a century—is now finding wide application as a result of recent developments in the field of semiconductors.

The Hall Effect—first reported in 1879—has remained a scientific curiosity, for all practical purposes, until very recently. The development of semiconductor materials for diodes and transistors has suddenly rescued this phenomenon from obscurity, and there are now a great many places in which it can be used to great advantage.

Back in 1879, the American physicist E. H. Hall stated in the American *Journal of Mathematics* that a current passed through a strip of metal at right angles to a magnetic field would induce a voltage along an axis at right angles to both. With metals, it was a very small figure indeed, amounting to several millionths of a volt for the range of magnetic fields and currents that can conveniently be obtained in a laboratory. The advent of the semiconductor as a practical device brought the Hall effect into prominence for reasons that are readily apparent when one considers how the effect arises.

THEORY

Let us first produce a visual though over simplified picture of how a metal conducts an electric current. Imagine a single row of atoms arranged like billiard-balls in a cardboard tube that fits tightly around them, each of these atoms consisting of a nucleus surrounded by electrons. A violent blow delivered to the billiard-ball at one end can then be imagined to knock an electron over to the next billiard ball which then finds itself unstable (since there are now more negatively charged electrons than there are positively charged protons in the nucleus). This billiard-ball in turn, kicks one of its electrons over to the next one and so on, the net result being the passage of a current of electricity from one end to the other. If there is a magnetic field at right angles to the tube axis, the field will cause the electrons to migrate in a direction perpendicular to the field and tube.

Substances that conduct electricity freely (copper, nickel, iron, etc.) have structures that do not allow the electrons to move very freely through the crystal lattice, and the average speed of the electrons, consequently, is relatively low. With semiconducting materials, on the other hand, it is just the reverse; there are fewer electrons (or the positive equivalent known as 'holes') but they are very much more mobile. As a result, semiconductors exhibit a much greater Hall effect. The Hall voltage for certain substances may be one million times as great as it is for a metal under similar conditions of current and magnetic field.

The polarity relationship of the voltage to the current and magnetic field is shown in Fig 1. With semiconductors that conduct electricity by the movement of 'holes' or positive carriers, the voltage polarity is just the opposite. The phenomenon is thus quite useful for semiconductor research as it gives information about the kinds of carriers in the material under investigation.

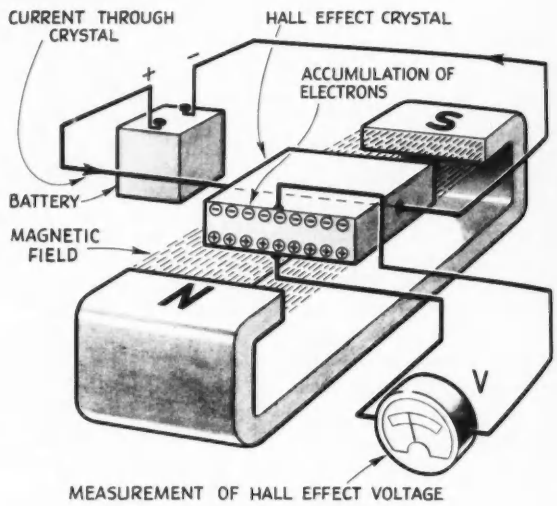


FIG. 1. Diagram illustrating Hall effect. Electric current along one axis of crystal and magnetic field along a second axis produces a voltage along the third axis that is proportional to the product of the first two quantities.

NEW APPLICATIONS

Since the Hall voltage varies as the product of the current and magnetic field, semiconductors that produce this effect can be used as instruments for measuring either of these quantities or any other quantity that can be converted into an electric current or a magnetic field. A magnetometer that was developed at the French Nuclear Study Centre at Saclay to measure the fields produced by large magnets of the type used in particle accelerators is shown in Fig. 2. The probe at the right contains a crystal that is an alloy of indium arsenide and indium phosphide. Its accuracy is extremely high, making it possible to measure fields of almost any strength to within 0·1 gauss. (For comparison, the magnetic flux densities in the loud speakers of domestic radio and television receivers is usually about 6000 to 8000 gauss.)

The earth's magnetic field (in order of 1 gauss) can be measured with a crystal of idium antimonide by using rods of mu-metal (a special high-permeability magnetic material) to concentrate the weak field of the earth. Such an arrangement can be made so sensitive, a movement of

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J. H. M. Sykes, a District Engineer in Britain's high-voltage grid system for seventeen years, is now the Editor of the monthly technical journal DIRECT CURRENT.

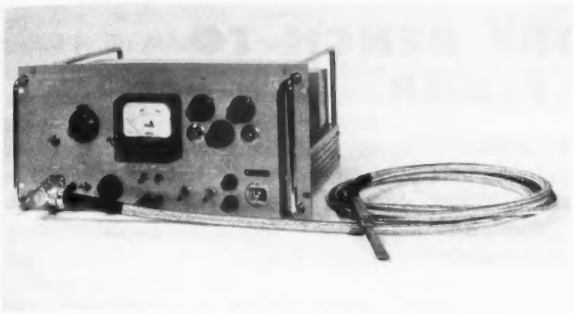


FIG. 2. Magnetometer utilising Hall effect. Probe at right contains semiconductor detecting element. *(French Nuclear Study Centre, Saclay)*

one angular degree from the zero position will change the power output by one ten-thousandth of a watt—enough to be easily seen on a sensitive meter. Hall effect devices can thus be used to prospect for minerals since they can detect the distortions in the earth's magnetic field produced by buried metallic ores such as those of iron, copper, and uranium. The advantage of Hall effect devices is their accuracy and the lightness of the associated equipment. One man can carry all the necessary paraphernalia for a survey whereas the alternative methods require power supply trucks and large-scale equipment.

Since the Hall voltage is the product of two quantities (current × magnetic field), it can also be used to measure electric power (current × voltage) by converting the voltage at the point one wishes to measure power into a magnetic field. This is easily done with a coil of wire (Fig. 3). This application is particularly promising for the high-frequency measurements associated with radar, communications, and missile control since it can be used at frequencies as high as 3000 megacycles/sec.; no other comparable device can operate with equal facility and accuracy in this region of the frequency spectrum.

The ability to multiply also makes the Hall effect useful in computers (Fig. 4), particularly since it can differentiate between positive and negative quantities—something many other types of multipliers cannot do. Again, it offers the additional advantages of linearity and fidelity over an extremely wide range.

The ability to multiply also makes it possible to modulate carrier waves for communication in a simple elegant way, requiring fewer circuit components than other schemes.

Hall effect crystals can also be used as amplifiers since the power output at the voltage terminals is greater than the power input to the magnet field; they can be made to amplify a very weak electrical signal by first converting it into a magnetic field with a coil. The amplification achieved so far (about five) is not as high as that obtainable with transistors but the Hall effect crystals are less temperature sensitive and can be used at higher frequencies.

The Hall effect can, in addition, be used to measure nuclear radiation exposure since this radiation affects the energy state within the crystal and thus has a bearing on the number of charge carriers available and their mobility. There is, within a limited range, a direct relationship between the Hall voltage and the amount of radiation received. Simple, small, portable dosimeters have been evolved but they must be regenerated by heating after exposure since the radiation has an irreversible effect on the structure of the crystal.

The Hall effect can also be utilised to produce simple computer switches, an electric compass, information decoders, frequency spectrum analysers, and the like; these and other novel applications are now being investigated.

It is possible to carry out measurements and other functions by means of the Hall effect with an accuracy greater than that of practically every other comparable device or method. There are still certain problems associated with their use, however. For one thing, a maximum possible efficiency of 17% (ratio of output to input power) is imposed by geometrical considerations. There are also difficulties due to the rectifying action of the semiconductor material and the junctions made with it for the external circuitry. These problems are, nevertheless, gradually being overcome.

Although Hall effect devices are largely independent of temperature in their basic action, crystals must be very carefully chosen for operation within particular temperature ranges. Temperature compensation devices have been developed for special applications.

It is highly probable that within the next decade the Hall effect crystal will be as widely known as the transistor is today—not only in scientific circles but in industry and even in the home.

FIG. 3. Circuit diagram of wattmeter utilising Hall effect.

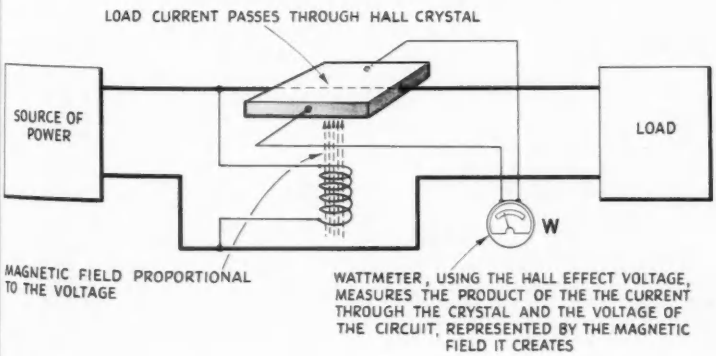
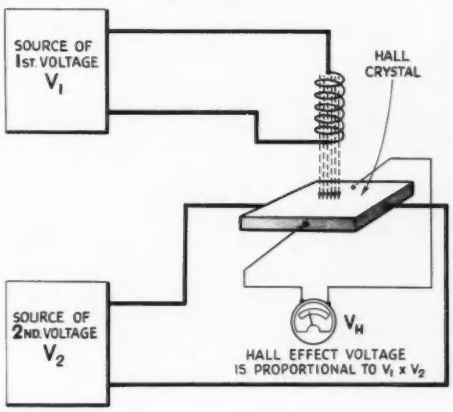

LOAD CURRENT PASSES THROUGH HALL CRYSTAL
SOURCE OF POWER
LOAD
W
MAGNETIC FIELD PROPORTIONAL TO THE VOLTAGE
WATTMETER, USING THE HALL EFFECT VOLTAGE, MEASURES THE PRODUCT OF THE THE CURRENT THROUGH THE CRYSTAL AND THE VOLTAGE OF THE CIRCUIT, REPRESENTED BY THE MAGNETIC FIELD IT CREATES

FIG. 4. General technique for using a Hall crystal as a multiplying device.



FROM LABORATORY BENCH TO FACTORY FLOOR

RITCHIE CALDER

The practical utilisation of scientific discoveries requires the combined efforts of the scientist, engineer, and business man. The successful development of a titanium-extracting process by Imperial Chemical Industries is a case in point. This article is the sixth and last in a series on the role of science in industry.

The relationships between the scientists, engineers, and business men in an industrial concern often begin to show signs of strain whenever the time comes to transfer laboratory results to the factory floor. Since big money is involved in the setting up of a new production unit, the hard-headed business men on the Board have to be satisfied on two points: one, that the scientists' ideas will work and, two, that there will be a market for the product. The engineers too have to be persuaded that what is feasible in the test tube or crucible will "pay off" when expanded to the production level.

At times, the scientists may feel that the Board is obstructive and the engineers may feel that the scientists are impractical, but the successful outcome of such a move depends on how the aspirations and reservations of all can be reconciled. One of the best examples is the experience of Imperial Chemical Industries with titanium.

BACKGROUND

Although the large-scale production of titanium has been a recent development, the metal was actually discovered in 1791 by the Rev. William Gregor, while investigating a black magnetic sand in the Cornish parish of Menachan. The English clergyman called it "menaccanite" but three years later a German mineralogist, Martin H. Klaproth, also discovered it while investigating Hungarian red schrol and named it "titanium" after the Titans of mythology. Klaproth's designation replaced the Cornish one.

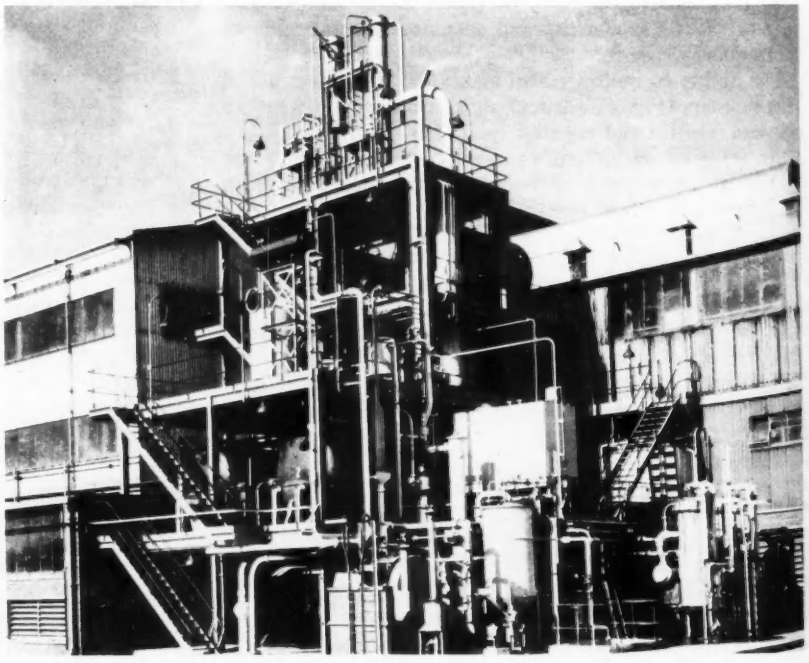
There is no scarcity of titanium; it is the world's ninth most plentiful element and is more abundant in the earth's crust than any of the common structural metals, with the exception of iron, magnesium, and aluminium. Its ores are found extensively in the United States, Canada, Sweden, Australia, Ceylon, India, Brazil, Norway, and Russia.

It may seem extraordinary that a metal which has been known for so long, and which is geologically abundant and metallurgically useful, should have become available only within the last few years; the explanation lies in the technical difficulties of extracting the metal from the ore. Titanium was isolated fifty years ago by converting the oxide to a tetrachloride and reacting this with sodium in a steel bomb. But the result was unsatisfactory because all the samples contained impurities, such as oxygen, nitrogen, and carbon, and were therefore brittle and quite useless for constructional purposes. In 1925, however, van Arkel and de Boer, working in Holland, succeeded in getting titanium of high purity by decomposing titanium tetraiodide on an electrically heated filament. The results tantalised the engineers by disclosing the exceptional qualities of the metal but the process for obtaining it remained far too expensive for practical use.

WORLD WAR II SPURS DEMAND

Immediately after the Second World War, the U.S. Bureau of Mines, using a process developed by W. J. Kroll involving the reaction of titanium tetrachloride with magnesium, produced the metal on a commercial, though still

ICI plant at Wilton for producing titanium granules by the sodium reduction process.



Ritchie Calder, science journalist and author, was recently appointed Burton Professor of International Relations at Edinburgh University.

expensive, scale. The demand was created by the need for a metal with a low weight, great strength and other properties suitable for high-speed military aircraft. Under the same compulsions, ICI became interested in 1949; its General Chemicals Division built a Kroll plant and, at the same time, began to explore the possibilities of a better and cheaper process using sodium instead of magnesium for the reduction of the titanium tetrachloride. Serious doubts were expressed, but further work showed that the difficulties expected in using sodium had been greatly exaggerated. Experiments at the Widnes laboratory—initially on a 7-lb. scale—proved the value of the method and a pilot plant was set up; the decision was made to concentrate on the sodium method which yielded titanium as tiny granules, as opposed to the coke-like sponge obtained by the Kroll method.

At the end of 1953, ICI made a vital decision; without waiting for full confirmation of the pilot plant experiment, the Board decided to build a large-scale plant at Wilton, in North Yorkshire. The scientists had no cause, in this case, to complain of the tardiness of those who held the purse strings. There would have been every justification for a more cautious policy since the melting of titanium presented several entirely new and difficult problems.

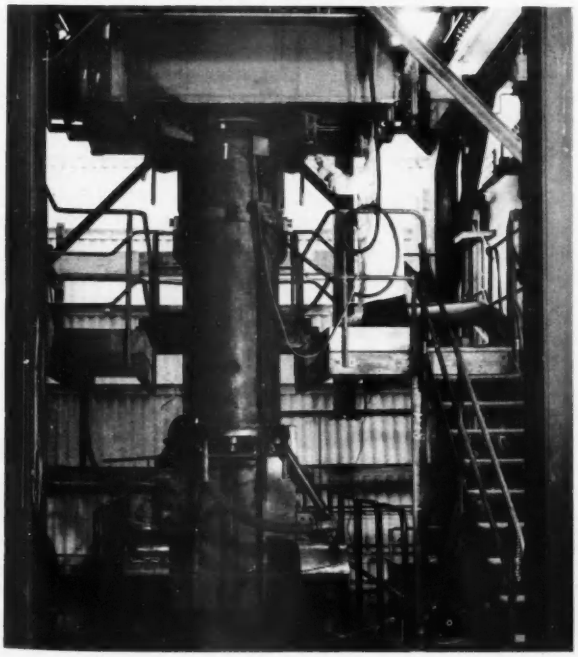
PROBLEMS

The melting-point of titanium is 1600°C—about 200° higher than that of steel. In the molten state, it readily takes up oxygen, nitrogen, carbon, and other elements; since small amounts of these "impurities" destroy the malleability of the metal, they must be excluded at all costs. This means titanium cannot be melted in air; the process must be carried out in a vacuum or under a blanket of inert gas, such as argon. Furthermore, the molten metal reacts with all the known refractories used for lining furnaces. So, while the chemists and extraction metallurgists were finding out how to produce the raw metal, a white-hot problem was passed to the physical metallurgists of the Metals Division in Birmingham.

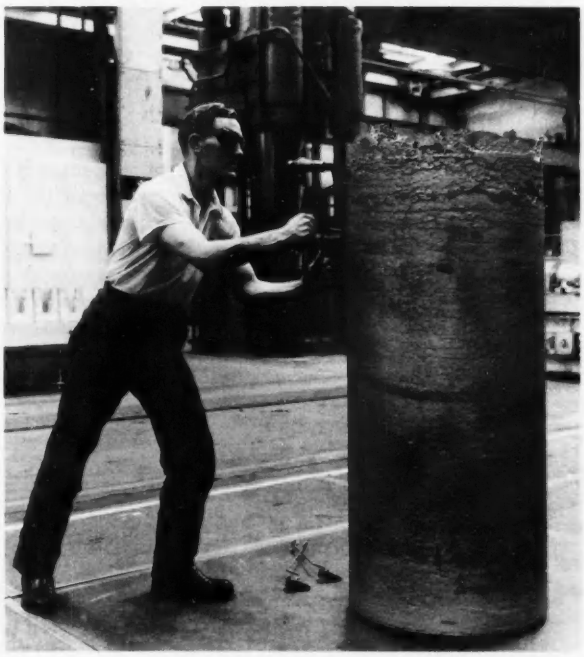
The Metals Division of ICI originated in the century-old Kynoch company, which had begun by making percussion caps and later turned to ammunition manufacture. Dissatisfied with cartridge brass made by others, they had decided to become self-sufficient by making their own metal. In 1926, Kynoch's became part of ICI, and by 1940 the ICI Metals Division had become the largest producer of non-ferrous metals in the Commonwealth. When the problem of nuclear energy arose, the Metals Division was given the task of producing membranes with 160,000 holes/sq. in. for the mass-diffusion process which separated U235 from U238 (later specifications were even more exacting) and this porous metal had to be supplied in millions of square feet. The first rod of uranium to be produced in the United Kingdom was extruded by the Metals Division in 1942.

With this experience behind them, the experts of the Metals Division already regarded themselves as "nursemaids" of the fractious, temperamental, new metals. As a result of an intensive laboratory investigation, they were by 1953 so confident they could discipline titanium, they undertook to get a commercial-scale melting-plant designed, built and operating to meet the needs of the aircraft industry within two years. This was to coincide with the parallel undertaking by the General Chemicals Division to provide a full-scale

Electric arc furnace at the Wilton Works for melting titanium ingots weighing up to 4200 lb.



The first 4200-lb. titanium ingot produced at ICI, the first in Europe.



plant for producing the raw titanium.

The major technical problems of melting titanium had already been solved in the laboratory. On this scale, it was fairly easy to design and operate vacuum melting equipment which would exclude air and contaminants, but there was still the problem in a large-scale production unit of contamination from the furnace lining. Refractory materials obviously could not be used, but how could a temperature of nearly 1700°C be sustained without a high-temperature lining? Water-cooling was the solution. The copper crucible was surrounded by an outer jacket in which water circulated continuously and the molten titanium in contact with the cooled surface froze, forming a thin titanium shell inside which melting took place.

Another problem that had to be met was the contamination by the electrode. The process required the heat of a powerful electric arc to melt the metallic granules but the right electrode material was not easy to find. Because of the need to get a pilot plant into operation at the earliest possible moment in order to obtain operating experience before finalising the details of the large-scale plant, a graphite electrode was adopted and extreme care was taken to keep it from contaminating the melt.

The pilot plant melted its first ingot on January 1, 1954—only two or three months before the final details of the large-scale unit had to be "frozen".

THE PUSH TO COMMERCIAL PRODUCTION

At this point, Dr W. H G. Lake, then assistant research manager, was put in charge of the titanium project. This enterprise, with the cost of research and of the extraction plant, would bring ICI's capital investment in titanium almost up to £10 million. Because of the metal's strategic potential, the Government had guaranteed a market for most of the raw metal produced at the Wilton plant for some time to come, but the Metals Division was on its own and developed the melting furnace and the rolling and fabricating equipment at its own risk. What that risk meant was to become apparent by 1957, when the Government decided to curtail the aviation programme in favour of guided missiles—a much less promising market for titanium.

Lake and his team moved to the pilot plant and, simultaneously, the engineers and builders got busy on the production unit. This was the crucial stage. Dr Lake had no production experience of this sort on the one hand and the engineers on the other were unfamiliar with the peculiar habits of titanium. The Metals Division Board told them to get together, pool their ideas and learn from each other, and they did, merging into a unified team. Two months on the pilot plant was all that was needed to give them the confidence they needed to tackle commercial scale production, albeit in a series of small furnaces. By the promised date—1953 plus 2—eighteen melting furnaces were in operation, with an output of 1500 tons a year. The first furnaces produced ingots weighing 400 lb.—a far cry from the 7-lb. specimens produced in the laboratory.

One by one the snags were overcome, defects remedied and mistakes written off to experience without recrimination. Problems which had been solved relatively easily in the laboratory and even on the pilot plant, had to be solved all over again. Early experience showed, for instance, that graphite electrodes had their disadvantages in commercial-scale production. Although all possible precautions were taken to avoid contaminating the molten titanium with carbon from the electrodes, the resulting ingots still did not achieve a consistently high quality. So a different technique was worked out—one that might be called the "stalagmite" method. This consisted of making the electrode itself of titanium by compacting titanium granules into blocks having the necessary electrical characteristics and making these blocks into long rods weighing 1 ton each. When the arc was struck, the electrode itself proceeded to melt and the ingot grew, like a stalagmite, from the crucible floor. Yet another step towards reliable wrought titanium was taken with the decision to re-melt each ingot, so ensuring still higher purity; the ingot itself acted as the electrode the second time.

Forging a titanium ingot with a two-ton pneumatic hammer.

Practical experience soon made it possible to increase the size of the crucibles and hence of the ingots. The earlier ingots, with the diameter of a fire-log or a club Stilton, had a crust or rind which had to be machined off and retained heat from the furnace for only three minutes or so—inconveniently short for forging. Today, ingots weigh one or two tons, have the breadth of a Parthenon pillar, and a rind that is

relatively thin and easily removed. The ingot retains its heat for over 15 minutes —ample time for the forgemen to handle the ingots with mechanical grabs and squeeze them into billets with a power press as deftly as a grocer shapes a pound of butter.

In the past five years, technical knowledge, aided and abetted by laboratory research, has accumulated so rapidly that the Company has twice replaced its entire melting facilities. Three furnaces are now sufficient to produce over 2000 tons a year. (In 1948 the entire world production of titanium was only 3 tons.) The three furnaces embody a vacuum system developed by Heraeus in Western Germany and adapted to the special needs of the Metals Division. One special feature is, in effect, a vacuum lid so devised that the change over of the ingot-electrode for the second melt can be made without unsealing the vacuum. The first ton-sized ingot was produced within two months of the furnaces being delivered; a few days later, an ingot weighing 4200 lb. —the biggest ever produced outside the United States—was melted.

During this entire period, the design engineers had to bear in mind yet another disturbing fact—whenever hot metal and cold water are in close proximity, there is an outside chance of an explosion if things go wrong. The Metals Division was taking no chances of injury to personnel in such an emergency. The furnaces are installed inside explosion-proof walls so that any incident will discharge itself upwards; operations are remote-controlled from a console at which sit two "invigilators" who can see from gauges and twin optical screens exactly what is happening within the furnace as the melt proceeds.

The most recent technical breakthrough has been the development of methods by which scrap titanium can be used. In the dressing of the ingots and forged billets, and the fabrication of titanium products, "waste" shavings of the expensive metal mount inexorably. The problems of using such scrap in a melt were many and difficult but they were eventually overcome. In addition to using up its own scrap, ICI now buys it back from customers.

However, melting the titanium is only one part of the story—handling the metal once it is produced is another. Once the ingot is forged, the billet has to be machined to remove the oxidised layer; it is then heated again, and hot-rolled to suitable size for processing into sheet or rod. At first, Metals Division adapted its experience and its plant used for copper and brass rolling at Birmingham, but the handling of titanium came to interfere with other non-ferrous metal operations and the Board sanctioned the building of a titanium-rolling mill at Waunarlwydd, in Wales.

"FIND NEW MARKETS!"

A normal business precept is: "Be sure of your market." When the Metals Division embarked on its costly titanium adventure, there was the predictable market of the Government's aircraft programme. Titanium was ideal for supersonic machines, with its unique strength-to-weight ratio (it can be made as strong as high-tensile steel by alloying, yet has only half the weight). It was embodied in military aircraft like the P.1, Sea Vixen, Scimitar, Victor and Vulcan as well as in civil aircraft like the Comet, and Britannia, and in engines like Rolls-Royce, Avon, Conway and Tyne and Bristol Proteus.

Then the military requirements changed and civil aircraft requirements were not a commensurate substitute. It looked as though ICI had been caught out, but the change from an apparently assured market to a less certain one was itself a challenge to the scientists and salesmen. The scientists knew its unusual properties—titanium and its alloys can withstand attack by a wide variety of aggressive chemicals, including chlorine, chlorite and hyperchlorite solutions, nitric acid, metallic chlorides, sulphides and organic acids. Its resistance to the attack of sea water is phenomenal; in conditions so bad that even cupro-nickel may perforate in 500 hours, titanium in sea water appears to have a virtually unlimited life. For use in marine as well as chemical functions —even at comparatively high temperatures—its value is apparent. It can also be used as a lining for other cheaper metals at points of contact with corrosive fluids. The job of the Metals Division is to find and demonstrate more ways in which the present and potential output can be employed outside the aviation industry.

One asset is the progress in price-saving. Half a century ago, aluminium was almost as much a specialised metal as titanium is today, yet price-reduction made it both an industrial and domestic necessity. ICI General Chemicals Division has always supplied titanium at, or even below, the world price. In 1953 the world price was 45*s.* a lb. and by 1959 it was down to 11*s.* 6*d.* a lb. It is still tending to fall as a result of the constant improvement in production methods and efficiency. The average price of sheet in 1953 was about 260*s.* a lb.; today it is 106*s.* a lb. At every revision there is a cut.

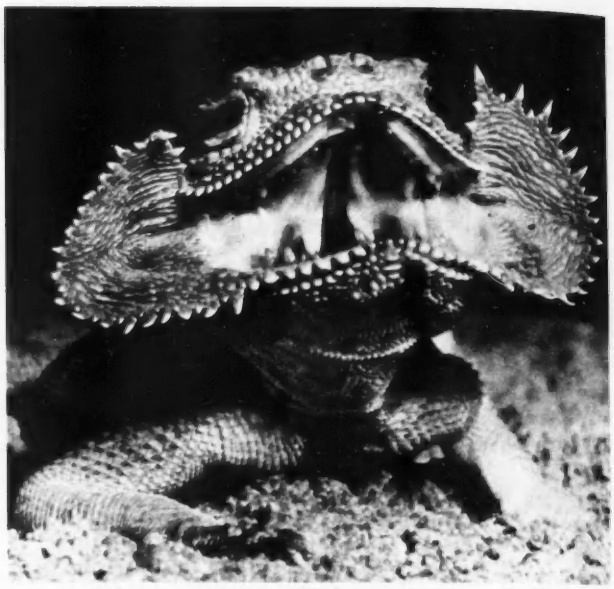
PROGRESS TOWARDS "NEW" METALS

As the Metals Division Board watch their production and sales charts, they are tempted to compare them with what they might have been if the Government-promoted demand had been fulfilled; they are good, but they might have been that much better. There are no recriminations. If there had not been the urgency of a Government requirement, and ICI had "gone after titanium" only when the commercial market had suggested likely uses, they would not have cracked the problem. They would not have had the experience of large-scale vacuum melting, they would not have entered the field of "new" metallurgy so dramatically and so quickly, and they would not now be applying the same experience to zirconium.

Zirconium is a metal of great importance in atomic reactors. Although it is another tricky metal with production problems similar to those of titanium, the Metals Division can handle it nonchalantly because of all the lessons acquired from titanium. Now producing beryllium, hafnium, niobium, and vanadium as well, they can claim to be in the forefront of nuclear metallurgy.

So, in this instance at least, it was the Board which set the pace for the scientists and the scientists who led the engineers. The outcome was a team which is right in front in industrial metallurgy, and which thinks of the transition from the laboratory bench to the production line as a natural progression.

THE BOOKSHELF



A sand-agama with flaps of skin spread out to simulate a gigantic mouth and frighten off its larger enemies. From *The World of Amphibians and Reptiles.*

The World of Amphibians and Reptiles

By Robert Mertens (*London, George G. Harrap, 1960, 207 pp., 63s.*)

In England we so seldom see a reptile or an amphibian wild that their true nature and importance in the world are not appreciated by us. But everyone who goes to Africa, or even to the wilder parts of the United States, is immediately confronted by reptiles living all over the place, and in many parts of America varied forms of frogs and newts are a familiar sight.

Thus, this magnificently illustrated book by Robert Mertens, translated from the German by Dr Parker of the British Museum, will be a revelation to most people, for it brings together a wonderful collection of photographs of living animals, including some greatly enlarged, such as the head of the Moloch lizard shown five times natural size, and some viewed from unusual aspects, and uses them to illustrate an admirable text in which many of their activities are set out and considered. The work was printed in France and contains well over a hundred plates, a high proportion in colour, which do immense credit to the technical skill of the printers. In fact, regarded merely as a collection of pictures, it is most attractive.

The book covers a wide field, giving most prominence to the exotic forms, and although it necessarily makes use of scientific terms, it is in general easily understandable by anybody who is likely to be interested in the subject. There is a short account of the ancestry of the two groups, which is perfectly adequate. Chapter 2 gives an excellent account of geographical distribution—in the sense of distribution over the world, and of restriction of certain types of animal to special environments. Then, very logically, the author discusses the bodily form and locomotion of amphibia and reptiles, and something of the relationship between the animal's habits and its powers of locomotion. Then he goes on to discuss external factors, temperature, and so on, which help to control the distribution of reptiles—how far, for instance, cold winters limit their spread. Then he discusses food and feeding, protective devices, and the habits of the animals—how far they exist in communities and how far they are solitary. The book goes on to discuss the secondary sex qualities which they show, their modes of reproduction, something of the course of their development and growth and, finally, records of the age to which individuals may live, the common toad, for instance, having a record life span in captivity of thirty-six years.

The book is excellent both in text and illustration. Without being completely technical, it gives a great amount of information, some of it certainly difficult to find elsewhere. It is an admirable piece of actual book making. D. M. S. WATSON

Department of Zoology, University College, London

The Geology of the U.S.S.R.

By D. V. Nalivkin, translated by S. I. Tomkeieff (*Pergamon Press, 1960, xii+ 170 pp., £5*)

This book of 150 pages presents an account of the geology of one-sixth of the surface of the Earth. Supplied in a folder with the book is an excellent map of the Soviet Union published by the Ministry of Geology in two sheets on a scale of 1:7,500,000. This map, a fine example of colour printing which contains over 100 shades of colour, has legend and place names printed in English. Highly useful in itself, it could be employed, if required, as a key to the larger scale geological maps of the U.S.S.R. which have become available in the last few years and which have a Russian legend.

Academician Nalivkin has arranged his text in ten sections, each of which deals with a region which has a common geological history such as the Russian Platform or the Pacific Ocean Geosyncline. Every section takes up in turn the relief, stratigraphy, tectonics, magmatic activity and economic deposits of the region. The treatment is concise and few words are wasted. It is naturally most effective where the topic is one that can be dealt with in summary fashion. With this book and map one can discover what are the principal kinds of rock in any part of the Soviet Union, how old they are, over how large an area they outcrop and what economic use they may have.

The accounts of the economic deposits

are brief and usually do no more than indicate the nature of the geological setting of the deposit. No figures of production are given but the importance of any mining field to the Soviet Union is indicated in general terms. These accounts do, however, provide a resumé of the geological factors which must influence the location and possible expansion of Soviet industry. They provide very clear indications as to the growing points of the future, and, as they are plainly written without technical jargon, should interest anyone concerned with future development in the U.S.S.R.

The geologist will be hampered by the lack of references. Indeed, hardly a single geologist is named in the text so one cannot establish who carried out the work on which an account of a district is based or when it was done. No bibliographical details of the Russian text are given and it is not clear when it was published. The geological map is dated 1957. There is no mention of the age determinations of Pre-Cambrian rocks carried out by Polkanov and others which one would expect to find here if the text was prepared after 1957.

English speaking geologists are already in debt to Prof. Tomkeieff as an interpreter of the contemporary geological scene in the Soviet Union. This book will increase their indebtedness. It is a pity that the publishers were not able to provide a more substantial binding for a book which can be expected to find much use as a work of reference. J. SUTTON

Professor of Geology,
Imperial College, London

Phosphorus Metabolism of Brain

By P. J. Heald (*Pergamon Press, 1960, vii+195 pp., 19 figures, 42s.*)

We know little as yet of those complex biochemical and physiochemical events which underlie the activity of the central nervous system and are modified by emotional and environmental changes and by the use of drugs. Although much interest has been taken in the effects of drugs on the brain, studies on drug-action have not so far helped very materially in gaining a detailed insight into the working of this organ. The successful use of drugs as tools in the study of the peripheral nervous system and the cardiovascular system has not been repeated in the brain. The difficulty is due not only to the great complexity of the brain but because it is virtually impossible to be certain that studies made upon tissue slices, homogenates or mitochondria are displaying events related at all closely to those which go on in the intact organ which is under constant organised nervous influences from other regions. We are therefore still unable to say precisely how central nervous system depressants such as general anaesthetics, tranquillisers or hypnotics act, nor can we say how convulsants exert their effects upon the brain but it is now possible to recognise that certain biochemical events accompany recognisable pharmacological actions.

This short book deals with the metabolism of phosphorus-containing compounds in brain tissue. It is divided into five main sections which deal with phosphorus metabolism *in vivo* in both the normal and in altered functional states, with phosphorus metabolism *in vitro* including a chapter upon the effect of drugs. It is a well-written, easily readable account of a complex field. The author adopts a critical approach to the subject and sets out clearly the difficulties which must be faced in the design of suitable experiments and in the interpretation of the results. After reading it, the present position in our limited knowledge of the nature, function and distribution of phosphorus compounds in the brain and their significance in its activity becomes clear and the need for continued investigation is very obvious. The book is well documented and well worth possessing. There are ample references to the literature and a useful section on analytical methods.

J. J. LEWIS

Institute of Physiology,
Glasgow University

Nuclear Propulsion

Edited by M. W. Thring (*Butterworth, 1960, 300 pp., 50s.*)

United Kingdom post-war capital expenditure on defence projects has consistently been less than 10% of that in the United States. One of the results has been the continued technological dependence of this country on the U.S. for advances in such fields as rocket propulsion and, save for one non-mobile exception, nuclear reactors. In the U.K., there is at present no prospect of any civil type of nuclear-propulsion unit. For defence purposes, the Admiralty has two nuclear-powered submarines on order, one of which will incorporate an American reactor. The Americans, on the other hand, have launched a dozen nuclear submarines, and have another forty in various stages of construction. Moreover, they have launched the nuclear-powered carrier *Enterprise*, the largest ship in the world, and *Savannah*, a nuclear-powered cargo- and passenger-carrying merchant ship.

In the face of this severe transatlantic unbalance, the publication of *Nuclear Propulsion*, consisting of independent contributions from British authors, most of whom are at Sheffield University, is a brave and interesting effort at disseminating information. Unfortunately, there is no editorial introduction or preface to explain the scope and purpose of the book. This leads to a lack of unity in the approach to each section. On the one hand, the subject of jet and rocket propulsion is dealt with in a commanding and advanced manner whereas, on the other, too wide a range of reactor topics is discussed, resulting in little more than a cursory and sometimes repetitive inspection of theoretical, but often not practicable, reactor possibilities. Little purpose is served in a short book on propulsion reactors by comment on natural uranium-graphite moderated reactors. Yet we have a discussion of this type, including a figure of Calder Hall, and a sketch of the Windscale and Calder fuel cans, in at least four chapters. A woolly approach to economics is probably responsible for the somewhat indiscriminate selection of reactor topics. It is misleading to say, as on page 205, for example: "Nuclear power, it is anticipated, will, in the next few years, be nearly competitive with conventional power stations on fuel costs . . ." The point is not sufficiently stressed that, apart from nuclear marine projects, there is little immediate prospect of any kind of nuclear propulsion. Even in the nuclear marine field, the reader could be forgiven for not gathering that the pressurised-water reactor is the only type that has so far been sucessfully

B.Sc.
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The increasing importance of Science in industry, commerce and education opens up many worth-while opportunities for Science graduates. Wolsey Hall (est. 1894) provides postal tuition for the examinations leading to the B.Sc. degree of London University, for which residence at the University is not required. **Prospectus** (please mention examination or subject) from E. W. Shaw Fletcher, C.B.E., LL.B., Director of Studies, Dept. WM8,

WOLSEY HALL
OXFORD

developed. One chapter on reactor topics is, however, exempt from the charge of economic woolliness. In a wholly admirable contribution by Mr Norton of Yarrow & Co. Ltd, *Marine Developments in the Nuclear Age*, the problems of design, building, operation and costs of nuclear ships are penetratingly analysed. The second round of tenders for a U.K. merchant tanker were submitted by selected manufacturers to the Ministry of Transport six months ago, and a decision on this project is now long overdue. There is, moreover, no inclusion in the recent Civil Estimates for a nuclear vessel. This is a measure of our position in this technology.

R. E. STRICKLAND

Department of Mechanical Engineering, Imperial College, London

Surface Microtopography

By S. Tolansky (*London, Longmans, 1960, 296 pp., 55s.*)

The title of this book is not strictly accurate, but on reading the name of the author one is not surprised to find a report on the uses of multiple-beam interferometry rather than a general acount of the study of microtopography.

During the past fifteen years Prof. Tolansky has perfected the elegant methods of multiple-beam interferometry and together with a band of research students has applied these techniques to a wide variety of problems. The present book is really an atlas of their observations and contains 359 plates most of which have not been published in book form before.

After discussing the experimental techniques an account is given of the topography of natural crystal faces on diamond, quartz and silicon carbide; then the features of cleaved and etched faces are described. There is a fascinating description of the oscillation of quartz crystals. The chapters on metals deal with slip markings and the more complex surface deformation effects produced by grinding, spark erosion and the high velocity impact of water droplets. The indentations produced by hardness testing of metals have been studied in detail and here the experimental technique is particularly successful in demonstrating the surface tilting occurring adjacent to the indent.

As Prof. Tolansky points out, multiple-beam interferometry has its limitations. The method is ideal for surveying the undulations of the Fens, but is of little help for studying the topography of the more interesting mountainous country in the North. Under the circumstances the author has done well to extract so much of interest when working under so many self imposed limitations.

The book is excellently produced; it is printed on glossy paper throughout and the quality of the photomicrographs is superb, but the author's use of English is at times very loose. However, the book may help the author to achieve his aims in getting his experimental techniques more widely used by others.

J. NUTTING

Professor of Metallurgy, Houldsworth School of Applied Science, Leeds

A Ciba Foundation Symposium on Congenital Malformations

Edited by G. E. W. Wolstenholme and Cecilia M. O'Connor (*London, J. & A. Churchill, 1960, xii+308 pp., 45s.*)

As progress in medicine has brought many diseases of adult life under control, the rather intractable group of congenital malformations is beginning to loom larger, and in the past decade or two, there has been a marked revival of interest in their study. A Ciba Foundation Symposium attended by some twenty-nine workers in this field which was held in January, 1960 included experimentalists and clinicians from several countries and the twelve papers presented, together with the discussions which followed, give an excellent cross-section through the present state of the field.

Congenital malformations range from defects which are quite incompatible with life like anencephaly (failure of dorsal closure of the brain) down to conditions which are almost normal like "runts", that is, animals significantly smaller than the rest of the litter. Some of them are common in all human populations (like anencephaly, spina bifida and congenital hydrocephalus); others are rarer. Adding them all together, the total load of congenital malformations in this country and in Japan is much the same, but some of the conditions which are common in Britain are rare in Japan and vice versa. Fifty years ago, there were still sharply divided schools of thought favouring either a hereditary or an environmental origin of congenital defects. We know now that almost always, congenital malformations are due to an interaction between the two. But for any one type of anomaly, their relative importance may be quite different. Perhaps the most striking discovery of the last two years is that some common and well-known human defects like mongoloid idiocy are due to an unbalance of the chromosome set: such idiots possess one of the smallest chromosomes in triplicate rather than double, and comparable situations have since been discovered in at least two other conditions. At the other end of the scale are defects traceable to maternal infections during pregnancy, such as with German measles (rubella). However, even where the precipitating cause is clearly external, the degree of resistance to it is often largely under genetic control. Thus cleft palate can readily be produced by the administration of cortisone to the pregnant females of one strain of mice, but not to those of another. Some chemicals are teratogenic in animals when administered in heavy doses, but some, like actinomycin-D, will damage the offspring in doses which are quite non-toxic to the mother. In certain cases, both excess or deficiency of a vitamin during pregnancy may cause congenital malformations. Some antimetabolites clearly produce their effects by sidetracking a substance necessary for normal development. Many cases are now known where experimental animals can be protected against the effects of a teratogen by the simultaneous administration of certain other substances, and it may be hoped that a study of such interactions will lead to a fuller understanding of how teratogenic agents produce their effects.

These and many other results discussed during the symposium show the complexity of the causation of congenital malformations and the many problems which will have to be solved before practical results in prevention can be expected.

H. GRÜNEBERG

Experimental Genetic Research Unit, Medical Research Council, London

Tools of Biological Research (Second Series)

Edited by Hedley J. B. Atkins (*Blackwell Scientific Publications, Oxford, 1960, xii+175 pp., 37s. 6d.*)

This book is a collection of papers presented at a conference held in Guy's Hospital in 1959. The scope of the conference may be judged from the titles:

Electron Spin Resonance, Electroencephalography, Paper Chromatography, The Ultracentrifuge, X-ray Studies in Biological Research, Fluorescent Antibody Techniques, Phonocardiography, Vectorcardiography, The Cathode Ray Oscillograph and its application to Electromyography, Microradiography.

The purpose of the publication of a collection of short articles on such varied topics is not clear—even when presented by authorities in their subjects. Very few of those present at the conference could have derived equal value from all the papers, and the same is true of the reader. Considerations of space prohibit adequate discussion of most of the topics, except on a very elementary level, especially as some authors have discussed results rather than

techniques at considerable length. Perhaps the best justification for a book of this type is as an introduction to the literature. Some authors have provided well chosen bibliographies, while others have been content mainly with references to their own work or (in one case) with no literature references.

In view of these shortcomings, it is not surprising that the most sucessful articles are those dealing with a specialised and strictly limited field, where methods and results can be presented concisely. Among these is the paper by R. G. White on the Coons fluorescent antibody technique. In this method antibodies are labelled by chemical conjugation with a strongly fluorescent dye, and are then used as a histochemical reagent to detect the homologous antigen in tissue sections. It is thus possible for the first time to locate the sites of specific protein synthesis unambiguously. The possibilities of this method are still almost unexplored and its inclusion in the present book is timely, it is illustrated by some excellent colour photographs.

Another valuable article is that of P. Johnson on the ultracentrifuge. The advent of a compact, self-contained commercial instrument has revolutionised the field. It has become almost indispensable for measurements of the molecular size and shape of large molecules, while recent theoretical advances have made it possible to extend the range down to relatively small molecules. The Reviewer would like to have seen some discussion of the preparative aspects of ultracentrifugation, as recent achievements—such as the availability of a commercial instrument for subjecting 100 ml. quantities of solution to centrifugal fields of 190,000 g. for extended periods—offer new prospects in the fractionation of biological polymers.

D. C. Phillips' review of X-ray studies in biological research succeeds admirably in conveying to the reader some of the excitement of recent advances in molecular biology.

Phillips begins with a lucid introduction to a notoriously difficult topic, and reviews some of the most recent developments culminating in an account of the recent brilliant successes of Kendrew and Perutz and their co-workers in delineating the topography of the myoglobin and haemoglobin molecules. More recent work suggests that it may even be possible to identify specific amino acids in the peptide chains (the so-called primary structure) in certain proteins. This article also is timely in presenting the results of recent physicochemical studies of macromolecules.

It is perhaps an indication of the heterogeneity of the material included in this book that this reviewer is not competent to give a valid criticism of several articles in it.

C. J. O. R. MORRIS

Professor of Experimental Biochemistry, The London Hospital Medical College

Axiomatics of Classical Statistical Mechanics

By Rudolf Kurth (*Pergamon Press, 1960, x+180 pp., 45s.*)

Dr Kurth's book is "an attempt to construct classical statistical mechanics as a deductive system, founded only on the equations of motion and a few well-known postulates which formally describe the concept of probability". With such a precise aim a highly mathematical presentation is unavoidable. This book, is therefore not for the layman, nor for the average physicist but for the pure mathematician.

The first chapter is a statement of the problem, namely how to characterise the solutions of the equations of motion of a very large number of particles. This is at first sight an impossible problem, since in general, at the present time, it is possible to write in a closed form the solution of only two interacting particles. However, it is the fact that we are dealing with a very large number of particles that provides a way out—the possibility of average solutions. Statistical Mechanics endeavours to define average properties of the system, evaluate them and justify their application to individual systems.

Before departing on this programme of giving a deductive presentation, Dr Kurth has a chapter on Mathematical Tools. This includes Set Theory, Mapping, and Measure Theory, the claim in the introduction that the reader is assumed to have only a knowledge of the elements of calculus and analytical geometry is a very ambitious one. For anyone not familiar with these concepts a much more detailed exposition is needed; on the other hand, for those who are already familiar with them, the chapter is unnecessary. It seems therefore, that the only reason for including this chapter is for the sake of completeness but this seems a rather trivial reason for such a large section of the book.

The remainder of the book applies these mathematical ideas to the theory of Statistical Mechanics.

The chapter on the phase flow of mechanical systems includes Liouville's theorem and the classical Ergodic Theory of Birkhoff, Von Neumann and others. Following this, the concept of probability is introduced using the ideas of Gibbs. The introduction of time dependent probabilities enables the approach to statistical equilibrium to be discussed. In the final chapter the application to individual systems is considered, the calculation of the macroscopic properties.

There are a few misprints, particularly on page 48, where dots, to denote derivatives, are missing. The notation is also sometimes confusing, for example, x is used for the *cartesian component of the displacement* of a particle and, on the same page, x for the total vector in Γ *phase space*.

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On the whole Dr Kurth succeeds in his stated aim. The style of the book, mainly in the form of theorems and their proofs, and its highly mathematical content means that its appeal will be limited. R. E. TURNER

The Clarendon Laboratory, Oxford

Problems in Photosynthesis

By W. Bladergroen (*Springfield, Illinois, U.S.A., Charles C. Thomas, 1960, 198 pp.*)

Short books on photosynthesis can only cover a few topics objectively and the preface would suggest that "Problems in Photosynthesis" sets out to do this. Dr Bladergroen has dedicated his book to Otto Warburg and this perhaps accounts for the unbalanced result. All the more radical claims of Warburg's laboratory are set out as the truth while work by Arnon, Calvin, Brown, Emerson and others is dismissed as unreliable, misleading or based on unsound hypotheses.

Values for the quantum requirement in photosynthesis below six are accepted without question and it is clearly stated that Warburg and Burk have solved all problems of the energetics of photosynthesis. The Emerson Co_2 burst "must be attributed to faulty manometric technique", yet Gaffron, Van der Veen and Brown and Whittingham have independently demonstrated the CO_2 burst by methods other than manometry. A single experiment of Warburg's using labelled Co_2, in which amino acids were more rapidly labelled than PGA, is quoted to dispute the validity of carboxydismutase as the main CO_2 fixing enzyme in photosynthesis. The author concludes from this experiment "that a chain of amino acids acts as a catalyst in Chlorella".

Water as the source of photosynthetic oxygen is dismissed and the author states categorically "we now know CO_2 photolysis to be a fact". Arnon's evidence for light induced phosphorylation is not accepted, it is held to be oxidative phosphorylation mediated by "induced respiration".

In every chapter of this book there is the same lack of objective assessment of the literature. Clearly this book cannot be recommended to undergraduates or to anyone not already familiar with the subjects discussed. To research workers in photosynthesis it is of use as a ready access to Warburg's work and literature. Of value too are the illustrations, especially the photographs taken in Warburg's institute.

Despite Dr Bladergroen's eulogy of Warburg's work an objective assessment of our present knowledge of photosynthesis shows Arnon, Calvin and others to have contributed rather more to it than they are credited with in this book.

R. G. HILLER

Department of Botany, Queen Mary College, London

Review on Weather Modification

First Annual Report by the National Science Foundation, Washington, D.C.

This short report provides an excellent survey of current work on weather modification in the United States, mainly in the sphere of rain-making, which is not one with a particularly happy history in the eyes of many meteorologists. Veraat conducted the first experiments on modern lines in Holland in 1930 by seeding cloud with dry ice (solid carbon dioxide), but the claims made were extravagant and many bodies in Holland and elsewhere discounted this work. In 1946, Schaefer in America liberated dry ice from the air above cloud-tops and soon afterwards Vonnegut found that microscopic silver iodide crystals (smoke) proved more efficient than natural sources as nuclei upon which ice crystals could build, some being large enough to fall.

Major American investigational projects followed these discoveries, and during the period 1947–52 hundreds of seeding flights were made, in addition to the release of nuclei from the ground. Similar investigations were also undertaken by several other countries. A real difficulty with cloud-seeding techniques has always been to assess rain contribution due to the seeding as, in many cases, clouds would have been expected to produce rain anyway and very optimistic claims were put forward by some commercial undertakings. In 1953 an Advisory Committee on Weather Control was therefore formed to look into the whole question in America, where there was a need for additional rain in many areas; the Committee was also to look into the potential for large-scale public and private exploitation. The group functioned until 1958. Its final report found that in certain circumstances, such as the seeding of winter storms in western mountainous areas, a real increase in rainfall of about 10 to 15% appeared possible, but that in non-mountainous areas no real increase in rain was established and that no evaluation was possible in investigations into hail suspension. Interestingly, British seeding experiments over Salisbury Plain during 1955–8 were reported by Oddie as apparently producing a decrease in rainfall. The Committee recommended that investigations should be pursued energetically with promotion and co-ordination by the National Science Foundation.

It is good to see in its first report that the Foundation is treating the whole problem of weather modification so realistically, and that the various avenues are being explored by Government departments and universities as well as by commercial consultants. Grants have been made on an impressive scale, well over one million dollars having been assigned for research. Activity is being directed in the realms of pure research into cloud physics at Chicago University, in actual field work by a number of varied bodies and in developing statistical tools to verify the truth of claimed modifications. The main accent lies in rain-making, but grants have been made towards research in hail suppression, and the report reviews efforts by Government departments in other fields such as modifying freezing rain to make it less dangerous (to aviation and transport), dispersal of fog and low cloud at airfields, control of evaporation from water surfaces by spreading protective chemical films, atmospheric pollution, and investigation into fire-producing storms.

It will be most interesting to see in future reports the progress being made in these various-fields. G. W. HURST

Principal Scientific Officer, Meteorological Office, Air Ministry

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SCIENCE ON THE SCREEN

L. GOULD-MARKS

Even the work of the Faculty of Filmology at the Sorbonne, and the extensive research carried out by Dr C. R. Carpenter and his colleagues at Pennsylvania State College for the Special Devices Centre of the U.S. Navy, have left the impact of films still imponderable. Fundamentally each film is an individual work, and must be appraised from that point of view.

Content is obviously more important than presentation, although photographic and sound quality help enormously in this sophisticated age. The films reviewed this month present an interesting cross-section of scientific films for precise jobs.

There is a series of diagnosis films for medical students, the record of an exploratory journey by a Royal Society Expedition and an industrially sponsored film on Ion Exchange Resins.

PHYSICAL DIAGNOSIS

A series of four films produced by the Wayne State University College of Medicine, Detroit, under the sponsorship of CIBA. All 16 mm. Sound. Colour. (*Available on free loan to specialised audiences from Filmservice, CIBA Laboratories, Horsham, Sussex*)

One of the basic troubles for the medical student, and even for the young doctor, is to be able to see the conditions which are the signs of various diseases. Many conditions are not seen by young surgeons because patients are not always available, and it needs considerable skill to examine the larynx or the ear. The same is true of gait and motility. These films have taken typical cases and filmed them in such a way that the characteristic condition is clearly shown, and can replace the somewhat haphazard availability of patients in the teaching hospitals.

Gait and Musculoskeletal Disorders

Running time 34 minutes. Made by William Green, M.D., Professor of Orthopaedic Surgery, Harvard School of Medicine

This film uses the camera as a straightforward scientific recording instrument to compare normal gait with that of twenty-eight patients suffering from diseases affecting gait and motility. These include muscular dystrophy, multiple sclerosis, Parkinson's disease, strokes, and poliomyelitis.

The Larynx

Running time 12 minutes. Made by Paul Holinger, M.D., Professor of Otolaryngology, University of Illinois College of Medicine

The first part, which explains the mechanics of speech by primitive animation, is of little value. The second half discusses different disorders leading to hoarseness, and includes some really excellent close-ups showing paralysis of the vocal chords, cancer, polyps, and other conditions.

The Ear and Hearing

Running time 28 minutes. Made by George Shambaugh, M.D., Professor of Otolaryngology, Northwestern University School of Medicine, and F. Darley, Ph.D., State University of Iowa

The introduction is somewhat elementary but is followed by first-class material showing the inside of the ear and various conditions of this organ.

Hearing tests are also shown, and three patients demonstrate the type of speech with different degrees of hearing loss.

Introduction to Speech Problems

Running time 27 minutes. Made by F. Darley, Ph.D., State University of Iowa, and C. van Riper, Ph.D., Western Michigan University

Here two speech therapists present twelve patients with speech difficulties that include stuttering, cleft palate, aphasia and dysarthria. They demonstrate not only the conditions but also what can be done by speech therapy, appliances, and surgery. Unfortunately, the American accent limits their value; the nasal timbre makes faults difficult to detect for the English ear.

South From Chiloe

16 mm. Sound. Colour. Running time about 40 minutes. Produced by the Royal Society. (*Available on hire, at the rate of 2 gns. per showing, from the Assistant Secretary, The Royal Society, Burlington House, Piccadilly, London, W.1.*)

This is a record of the Royal Society's five-man expedition to southern Chile from October 1958 to February 1959. The expedition covered much the same ground as Charles Darwin when he went on an expedition with HMS *Beagle*, a century ago.

The commentator is Dr Holdgate, the leader of the party. This film has all the cosy familiarity of Uncle Harry's holiday film, the only difference being that it shows the little-known flora, fauna, and indigenous people of this very little-known region. In this lies its strength and its weakness. It cannot be classified as a scientific film as the majority of its running time is spent in showing fairly general "travelogue"-type shots of scenic views and very little time is spent in detailed shots of the unique plants, insect and geological discoveries. As the expedition had a tight schedule and no professional cameraman, it is apparent that the making of the film was a spare-time activity. Interesting as it is—and it is very fascinating—it is a tragedy that more of the real scientific work was not shown. The local natives seem to be dying out rapidly and their way of life should be systematically recorded. There is so much for film to do in the realm of science, it is a little saddening and frustrating to see great opportunities partly missed.

All the same, it is most interesting to see even a superficial study of this remote area.

An Introduction to Ion Exchange

16 mm. Sound. Colour. Running time 27 minutes. Produced by Random Films for The Permutit Co. Ltd. (*Available on free loan from the Permutit Co. Ltd, Permutit House, Gunnersbury Avenue, Chiswick, London, W.4.*)

Here is a complete unit produced by industry for teachers; it consists of a film, a very well-produced handbook with a synopsis of the film, and a book of teacher's notes that contains the history, theory, practical applications and suggestions for further reading. The package should supply the necessary background for instructors who are not familiar with the subject.

The film shows the use of ion exchange resins and the theory which lies behind the applications, Experiments are very clearly demonstrated, but the diagrams and models suffer from economy—a very prevalent disease in scientific animation. Using a molecular model and simple animation, the principle of ion attraction and repulsion is shown understandably but not as well as it might be.

By using time-lapse photography, however, the three concepts of ion exchange are very clearly demonstrated (separation, substitution, and removal of ions).

This is a good, workmanlike film which should be of great use to students and technicians in industry.

LETTERS TO THE EDITOR

Employment Outlook

Sir:

It seems to me that Mr J. F. Peter, in his article in the February 1961 edition of DISCOVERY, on the scarcity of engineers and scientists, has made the mistake of confusing cause with effect. The strong swing of industry over to engineering, upon which the country must depend for its livelihood for at least another generation, will continue to create a demand for more and more engineers of a certain calibre and the ratio of grammar-school leavers trained for the work must be readjusted accordingly. If examined, therefore, at any time during the swing, the supply of young engineers should be more than is sufficient to supply the existing vacancies higher up the ladder. This allows for two most important factors:

(1) The need to select the most competent men for promotion and to deter the others from trying.

(2) To feed the increasing requirement which will be undoubtedly created by the advent of competent engineers in the aforesaid higher rungs.

I am afraid that far too many of the so-called engineering fraternity are not doing any more at the moment than making a passive contribution to their jobs and a great many more jobs which call for engineering knowledge are being held by the pseudo-engineer. These factors alone, if remedied by the influx of properly trained men through a competitive selection mechanism, will provide a forward impetus to the health and prosperity of both industry and the profession.

Obviously the time will come when Mr Peter is right: "the trees do not grow up to the skies"! This will be when too much of our industry is concentrated in the engineering sector of the economy and the reaction sets in. I, for one, can hardly believe that this will come for many years yet and I do not think, therefore, that any young man who has confidence in his ability to become an engineer should be in the slightest dismayed by Mr Peter's argument. D. A. HUTTON-WILLIAMS

West End Lane,
London, N.W.6.

Whither the Transport System?

Sir:

As you and I are scientists we try to get the facts right; would you very kindly publish some corrections to your note "Whither the Transport System", that begins on p. 43 of your January issue?

1. ". . . diesel electric locomotives . . . are creating unknown stresses in the track with their smaller wheels."

Electric traction on our railways is well over forty years old, and the effect of electric locomotives on track is very well known indeed. The knowledge of this matter has enabled us to build some well-riding Diesel locomotives, with equally small wheels.

2. ". . . the former railway companies failed to find a design of bogie suitable for stable riding at high speed . . ."

This problem was solved over twenty-five years ago by Sir Nigel Gresley of the LNER. Anyone who rode on his 100 m.p.h. trains from King's Cross to the North, 1935–39, knows how well they rode. In the early years of nationalisation, the Gresley bogie was abandoned in favour of the British Railways type; after years of struggle this is still unsatisfactory, and you will note that the coaching stock of the Great Eastern electrified lines, the Manchester-Liverpool-Crewe line, and the Glasgow electric, all runs on Gresley bogies, to which BR has reverted.

3. ". . . cutting costs of electrification . . . by going from 1500 V. DC to 25 kV. AC . . . lower capital costs by permitting the use of simpler motors."

The AC is transformed down and rectified, and DC motors are used in both cases. For the AC schemes the motors are slightly heavier and a little more costly.

4. "Before the transport system was nationalised, scientific activity in this area (research) was negligible".

The LMS Research Department was founded in 1933, and travellers into Derby all know its modern building. By 1946, when two of my friends were on the staff (numbering 150), there were sixty people with university degrees, or their equivalent. The LNER did all the well-known research into 4-aspect colour light signalling between York and Darlington before 1939. The GWR completed their researches into Automatic Train Control, and installed it, 25 years ago. The SR did the research needed to build and run the biggest electrified suburban network in Britain, and perhaps anywhere, before 1939. J. R. COTTRILL

Wyggeston Boys School,
Leicester

The following reply was written by the author of the note in question.—EDITOR.

Sir:

Mr Cottrill's letter is stimulating but the remarks in the January issue were nevertheless correct and objective.

1. There is very little operating experience in this country of electric or diesel-electric locomotives using small wheels. Moreover, because of the greatly intensified use of main line tracks in recent years, it is very important both from the point of view of safety and economics to investigate the possibility of prolonging the life of steel rails. An increase of even one or two years brings important economies over the whole system. Considerable research is therefore being undertaken into the stresses caused in rails by modern rolling stock from the point of view of fatigue life.

2. It is quite true that good riding was achieved by the former railway companies, although under somewhat different conditions. The Gresley bogie by modern standards is too heavy. The background dynamics of the riding of coaches are not really understood anywhere in the world and, in common with British Railways, all the Continental railway administrations affiliated to the International Union of Railways are carrying out a great deal of combined research in this field.

3. The 1500 volt DC system has for all practical purposes reached the limit of its development. The high-voltage AC system is less costly overall, even though DC traction motors are used; moreover, the system has far greater potentialities for improvement, as the French Railways have found.

4. The former railways companies, in collaboration with their suppliers, certainly experimented with new types of equipment, including signalling, but their research activities were very small indeed in relation to their size and scope. We are now paying the penalty of serious arrears in fundamental investigation.

THE PROGRESS OF SCIENCE

(continued from page 93)

The associated building to be constructed at the base of the tower will provide approximately 150,000 sq. ft. of floor space, most of it to be used for automatic telephone equipment.

DEEP-SEA DIVING WITHOUT "BENDS"

The revolutionary discovery by the Swiss mathematician Hannes Keller of "air" mixtures that would enable a diver to surface rapidly from great depths without getting the "bends" was dramatically demonstrated after a 510-ft. descent into Lake Maggiore and a simulated descent to 820 ft. in the French Navy's high-pressure chamber at Toulon.

An IBM 650 computer has now produced a 400-table chart of proper breathing mixtures for descents to 1312 ft. The spurt of progress made in this area should add new impetus to underwater exploration, underwater prospecting for minerals, salvaging, and the development of rescue techniques.

NEW USES FOR SUGAR

Cuba is the world's chief sugar-producing country and reduction of the world price of sugar, should the Castro Government dispose of its alleged large surplus stocks for quick financial return, could have a serious effect in other countries, such as British Guiana, which are largely dependent on it economically. Since 1945, world production of sugar has increased considerably and is now by far the greatest of any organic chemical. At the same time, fluctuations in the price have become severe in recent years, and all this focuses attention on the need to develop new industrial uses for it. The subject has been reviewed only recently in a Royal Institute of Chemistry publication by Dr L. F. Wiggins, entitled "Sugar and its Industrial Applications".

Derivatives of sugar itself (sucrose) have found diverse uses. The octa-acetate, known since 1887, forms a colourless, hard, resinous material on melting and cooling, and has been proposed as a material for laminated glass and for incorporation into synthetic resins; it is also used as a denaturant for alcohol. Similarly the acetate-isobutyrate mixed ester, a clear liquid of high molecular weight, is compatible with many synthetic resins and can be used in wood, metal and plastic lacquers and coatings. The non-toxic, non-irritant and tasteless sugar detergents have potentially important applications in the cosmetic, pharmacological, and food industries. Various alkyl derivatives of sucrose—that is, sucrose ethers—have potential applications as plasticizers and in coating compositions, whilst the product Hypnose, recently developed by the Dow Chemical Company, is non-toxic and finds use as a plasticizer for incorporation into cellophane, methyl cellulose and paper. Similar uses as detergents, emulsifiers, plasticizers and lubricants have been claimed for several other sucrose derivatives. Numerous attempts have been made to incorporate sucrose in synthetic resins and recently phenols have been reacted with sucrose and formaldehyde giving products similar to the familiar phenol-formaldehyde resins. These products have potential uses as laminating adhesives.

At the present time, more obvious use is made of the by-products of the sugar industry. The large amounts of beet pulp and molasses derived from the sugar beet together provide a valuable animal food, but the cane sugar industry produces bagasse, the fibrous part of the sugar cane, in enormous quantities. Even though much is used as fuel, embarrassingly large quantities remain. Bagasse now finds several important uses as building board, bagasse paper, cattle food, and as a source of furfural. In addition to the well-established manufacture of the insulating board Celotex, attempts have been made in Cuba and Puerto Rico to develop a hardboard. Bagasse paper has been produced in Peru since 1939 and is now widely used for wrapping-paper and bags. Production of bagasse paper has more recently been developed in Hawaii, and in 1958 newsprint production from the same source was established in Cuba.

A second by-product is the filter mud, or cake, which contains calcium salts and inorganic phosphate as well as proteins and waxy materials. It therefore has value as a fertiliser and a source of wax. Finally, the molasses—the uncrystallisable sucrose and other sugars—a very cheap source of carbohydrate; it is used mainly as cattle food and for fermentation. Attempts have been made recently to increase the nitrogen content of molasses and bagasse by treatment with ammonia. Although alcoholic fermentation of molasses for industrial purposes has been largely superseded by petroleum sources, other fermentation processes are still important. They include yeast and citric acid production and acetone-butanol fermentation, whilst the traditional rum industry naturally continues.

CRITICAL STATE OF CRITICAL TABLES

In recent years the rapid growth of the scientific literature has created serious problems in the preparation of critical tables. The quantity of recorded data in the fifty thousand or so scientific periodicals is now so enormous, the process of collection, analysis, appraisal, and selection of the final "best" values is a mammoth undertaking and a very lengthy one. The critical tables may well be out of date by the time they are finally published.

Probably the most famous sets of critical tables are the *International Critical Tables* issued in seven volumes between 1926 and 1930, and the *Landolt Börnstein Physikalisch-Chemische Tabellen*. The I.C.T. were prepared under the auspices of the International Research Council and the National Academy of Sciences by the National Research Council of the U.S.A. and are now seriously out of date. The German compilation is still being issued: many years have passed since the last revision of several sections was made.

These problems and new attempts to solve them were discussed in detail at one of the 1960 Gordon Research Conferences in New Hampshire. For example, when tabulating the density of a substance, the isotopic composition should be stated. In fact, full characterisation of the density of a material requires, in the ideal, tabulation of the density of all the pure isotopes. Obviously, considerations of this type would vastly increase the complexity of critical tables. Bridgman's conclusion is that "it will become increasingly difficult to exhaustively define the conditions that are necessary to obtain reproducible results. . . . Always will inspired common sense remain the most important requirement of those who are to produce the tables."

Two new approaches to the problems of actually preparing the tables have emerged in recent years. The first is the explicit planning of the experimental measurements in terms of the tables as one of the end products, and has been very successful in providing data in chemical thermodynamics for use by chemical engineers.

An entirely different method is in use at the Groth Institute of the Pennsylvania State University, which is concerned with information on solid-state materials—the physics and chemistry of crystalline materials, plastics, and glasses. Fifty years ago, substantially all the data was

summarised in P. von Groth's *Chemisches Krystallographie*; today, a complete revision of this would fill at least a thousand volumes each of 800 to 1000 pages. Obviously, publication of these by classical methods is impossible; it is too expensive, the storage space required would be excessive, the volumes would be out of date before they were printed and no one individual could ever find his way through such a vast mass of material. Recourse has therefore been made to the electronic computer.

Rather than printing out all the information, it is left implicit in the high-speed storage, computing programmes, sorting and correlating facilities of computers such as the IBM 704. All the data are put on IBM punched cards, ready for input to the machine via magnetic tape, and coded so that any necessary computations can be carried out on simple instructions given to the machine. Programmes have been developed for processing the data, correlating it, preparing rapid retrieval cards and tapes, as well as sorting and automatically printing desired information.

Already the Institute has some two million punched cards in its storage system; in the course of ten years the number is expected to reach the order of tens of millions. New though this method is, the volume of information already far exceeds that which can be handled economically for fast automatic search and tabulation. The next step is the use of large-scale tape-controlled computing equipment both for searching and computing purposes—and the cost of all this runs close to $1,000,000. Clearly such cost can only be met by Government funds, in this case provided by the United States Air Force Office of Scientific Research. This greatly contrasts with the $170,000 needed for the complete International Critical Tables thirty years ago and provided by 244 firms and individuals, together with the Carnegie Corporation and the International Education Board.

FRENCH SCHOLARSHIPS

The French Government is offering again this year scholarships for further study or research in France. The grants will be given for periods of between three and ten months during the academic year 1961–2. Candidates should hold a degree or equivalent qualification and applications from graduates in science or medicine will be particularly welcome.

Application forms and further particulars can be obtained from the Scientific Office, French Embassy, 22 Wilton Crescent, London, S.W.1. The closing date for application is March 16, 1961.

GRANTS AND SCHOLARSHIPS

THE NUFFIELD FOUNDATION

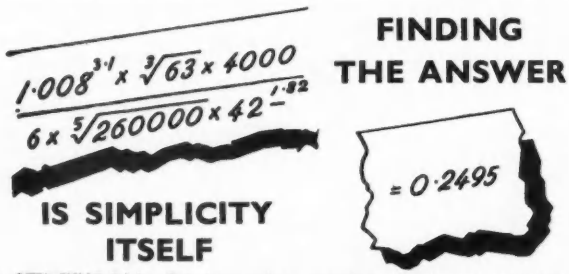
BIOLOGICAL SCHOLARSHIPS AND BURSARIES

THE NUFFIELD FOUNDATION, as part of its programme for the advancement of biological studies, is prepared to offer for the academic year 1961–2 a limited number of scholarships and bursaries to enable persons who have graduated in physics, chemistry, mathematics or engineering, but who have had no training in a biological subject, to receive such training in biology as will enable them in due course to undertake research and teaching in the United Kingdom in the biological sciences. The *scholarships*, which are senior awards, are intended for persons who have already undertaken some post-graduate research in their own subject. The *bursaries* are intended to enable those who have recently graduated to complete a course of training in biological subjects including, if considered necessary, a full honours degree course in biology. In the case of both scholars and bursars the Foundation will pay the cost of university and/or college fees in addition to a maintenance award. Graduates of universities in the United Kingdom, of either sex and preferably between the ages of 22 and 35, are eligible to apply.

Applications for awards in 1961 must be received before April 1, 1961, by The Director, The Nuffield Foundation, Nuffield Lodge, Regent's Park, London, N.W.1, from whom full particulars and application forms can be obtained.

L. FARRER-BROWN, C.B.E.

Director of the Nuffield Foundation



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SOCIETIES

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April 28: One-day Symposium on "Liquid Hydrogen as a Rocket Propellant". Eight papers. R.Ae.S. Hall, 4 Hamilton Place, W.1.

May 12: "Communications Satellites"—a one-day Symposium of eight papers at F.B.I., 21 Tothill Street, London, S.W.1.

June 26–28: Three-day "European Symposium on Space Technology", at F.B.I., 21 Tothill Street, London, S.W.1.

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LECTURES AND COURSES

THE second Public Lecture arranged by the Royal Institute of Chemistry, London Section, is entitled "The Story of Soap and the Growth of Modern Synthetic Detergents," and will be delivered by Dr. K. G. A. Pankhurst, D.SC., F.R.I.C., at Hendon Technical College, on Wednesday, March 29, at 7.30 p.m. Admission free.

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The theoretical part of the course, which includes the basic scientific principles, consists of about one hundred lectures; the majority of these are by members of the staff of the United Kingdom Atomic Energy Authority, but specialist topics are covered by members of the staffs of other bodies, including among others the Medical Research Council, the Agricultural Research Council, and the Royal Institute for Cancer Research.

Practical work is held in the laboratories of the Reactor School, and in various laboratories and installations in the Atomic Energy Research Establishment.

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For further information and forms of application, write to:

The Manager, Reactor School,
Atomic Energy Research Establishment,
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So much, that it sometimes seems we'll never catch up with all the great advances in knowledge—particularly scientific ones—even when they're being put to work in our own back gardens. How much do you know about 4-chloro-2-methylphenoxyacetic acid, for instance? It's this near-miraculous chemical—developed originally by I.C.I. for farmers to use in their cornfields—that so unerringly selects only weeds as its victims when you water your lawn with 'Verdone' selective weedkiller. What about gamma benzene hexachloride, another I.C.I. discovery? This is what puts the punch in 'Sybol'—the spray that spells death to sap-sucking pests in the garden. Such complicated chemicals—and a host of other weedkillers and insecticides, plant foods and fertilizers—are an open book to I.C.I.'s research chemists. But even *they* have a lot to learn yet—which is why their search for new knowledge, to aid the farmer and the gardener, goes on without pause.

THERE'S A LOT TO LEARN IN LIFE . . .

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